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Report 2193

SYNCHRONOUS ALTERNATOR ANALYSIS

October 1976

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U.S. ARMY MOBILITY EQUIPMENT
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A two-dimensional analysis of the cross section of a salient-pole, synchronous aircraft alternator under no load is reported. The nonlinear effects of magnetic saturation were considered.

The solution algorithm is a modified version of an algorithm previously used in the analysis of nonlinear, homopolar-inductor alternators. The details of the algorithm and the computer programs implemented on a minicomputer were described in earlier MERADCOM reports.

This report contains teletypewriter terminal printouts of actual minicomputer runs. A solution of the magnetic flux analysis was reached, but the number of iterations required to reach the solution indicates that problems remain in optimizing the numerical analysis used in the algorithm.

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SUMMARY

A two-dimensional analysis of the cross section of a homopolar-inductor alternator supplying a rectifier load was developed in previous investigations. In those investigations, the nonlinear effects of saturation of magnetic materials and nonlinear load currents were considered. Some of the partial-difference equations were parabolic. The analysis was applied for eddy currents, voltage waveshapes, and field excitations. An analysis was made on a 95-kVA homopolar-inductor alternator, 115/200-V; 3-phase; 3400-Hz; 40,800-rpm.

The computer programs which were developed were closely associated with the decision to use the minicomputer. Systems of equations normally require a large amount of computer time and are programs which are expensive to run. Both algorithm and computer implementation required investigations having many runs; therefore, application of dedicated minicomputer versus large frame became an economical decision. Fortran programs developed for this investigation are hardware dependent particularly for a virtual-memory technique for the storage of matrix data in mass-storage devices instead of a large-core memory.

The present investigation was limited to modification of these previously developed Fortran programs for the two-dimensional analysis of the salient-pole, synchronous alternator. Modification of the complex interrelated Fortran program and subroutines requires detailed and thorough study and evaluation for each modification.

This investigation is limited to no-load analysis of a model simulating a design of a 250-kVA; 120/240-V, 400-Hz, 8000-rpm salient-pole aircraft alternator. The discussion of the analysis emphasizes the interactive characteristics of the system of minicomputer programs applied in the solution of this different machine configuration.

PREFACE

This investigation, authorized under Project 1G762708AH67, was performed in the Electrical Equipment Division, Electrical Power Laboratory (formerly Laboratory 3000), US Army Mobility Equipment Research and Development Command. The work was performed under the direction of Dr. A. L. Jokl, Chief, Electrical Equipment Division. Dr. L. I. Amstutz assisted in the understanding of the computer implementation of the algorithm.

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SYNCHRONOUS ALTERNATOR ANALYSIS

I. BACKGROUND

This analysis of the salient-pole, synchronous alternator is related to a similar analysis performed on the homopolar-inductor alternator.

As in the homopolar-inductor-alternator analysis, the numerical method for solving the partial-difference equations is a strongly implicit iterative procedure taking into account the periodicity conditions of the salient-pole, synchronous alternator.

II. PURPOSE

The investigation demonstrates the analysis of salient-pole, synchronous machinery applying algorithms previously developed for the analysis of the homopolar-inductor alternator. This investigation required establishing a suitable rectangular grid system and selecting appropriate boundary conditions for the specification of the new-machine configuration.

III. PROGRAM PRINTOUTS

Several problem configurations for simulation of the salient-pole, synchronous alternator were tried. Such configurations were based on experimentation related to opposing characteristics of the simulation and the solution algorithm. Under load conditions, symmetrical boundary conditions should be specified for a pole pair. This configuration provided a grid space which was wide compared to its height. There is evidence that the solution algorithm converges more slowly when the grid space is wider than it is tall.

The result was to change to a single-pole, simulation model. The single-pole models were considered primarily to increase the rate of convergence of the solution and to reduce the execution time by specifying a fewer number of grid points.

IV. PROGRAM MODIFICATION

The analysis of homopolar-inductor alternators was developed as a general solution algorithm.[1] [2] It was anticipated that programs and subroutines previously

[1] A. L. Jokl and L. I. Amstutz, Report 2113," Nonlinear Homopolar Inductor Alternators on Nonlinear Loads – Part I," USAMERDC, Fort Belvoir, VA, October 1974.

[2] A. L. Jokl and L. I. Amstutz, Report 2114," Nonlinear Homopolar Inductor Alternators on Nonlinear Loads – Part II," USAMERDC, Fort Belvoir, VA, October 1974.

developed for the homopolar-inductor alternator could be modified to provide a solution algorithm for the salient-pole, machine configuration.

Programs and subroutines implemented for the solution algorithm combine to form a complex programming system. Modification of such a complex programming system is not a trivial exercise. Prior to modification, a time-consuming, detailed study is required on each portion of the program. Extensive use of common variables, multiple use of certain array or matrix variables, and logical branching are the programming factors requiring detailed analysis with modification.

The primary reason to modify the programs and subroutines was to make the change-of-boundary conditions resulting from different machine configurations. The boundary conditions are applied to values of the magnetic vector potential, A. For the left and right boundaries, magnetic vector potentials are identical for the homopolar-inductor alternator but are opposite sign for the salient-pole alternator. Similarly, lower and upper boundaries differ to permit a through flux for the homopolar configuration and to permit no through flux for lower and upper boundaries. Boundary changes in the algorithm were provided by introducing two new variables:

```
CSIGN = -1.0D00
CSYN  =  0.0D00
```

Assignment to alternate values of these variables and recompiling should make solution of the homopolar configuration possible:

```
CSIGN = 1.0D00
CSYN  = 1.0D00.
```

Modification for the purpose of boundary-condition changes represents planned changes. Other planned changes included modification of the subroutine SETUP used by program UPDATE to change values of certain key common variables. Other planned changes in UPDATE reduced certain duplicated teletypewriter input used in the description of the configuration. Additional, planned changes made to program FLUX speeded the graphic output of the machine configuration on the CRT terminal.

Certain other modifications of programs and subroutines provide an effort to shorten programs and to reduce program execution time. Particular attention was given to program SOLVE and its functions and subroutines – Subroutines SAEB and TCTB – which determine reluctivity of iron from magnetic induction by a table-look-up procedure. Table variables were changed from Fortran assignment statements to data statements. Saving in execution time by this modification was minimal because these subroutines were executed only when recalculation of reluctivities was required

instead of every iteration of SOLVE. Other attempts were made to reduce the number of calls of special functions that require input and output from disc files.

Program modification and program execution both produce a large amount of teletypewriter or line-printer output. In order to provide for a chronological order to modifications and program runs, a system Fortran compatible subroutine called DATE was devised. A patch was introduced in the system program EDITOR at the beginning of a file edit. These system applications and minor modifications provide a valuable documentation aid used on these programs and others in support of research and development projects.

The programs and subroutines modified during this investigation are shown in the Appendix.

V. DISCUSSION

This analysis essentially represents a numerical analysis for the solution of partial differential equations. The analysis consequently contains those mysterious tricks associated with solutions of partial differential equations and another set associated with numerical analysis. The analysis of equipment retains certain experimental characteristics in spite of all the efforts to refine the procedures.

The numerical solution is provided by an iterative procedure designed to give an approximation for the solution within a specified limit of error. The procedure does provide a solution, but the experimental investigations attempt to achieve the solution within a fewer number of iterations. A sluggish convergence to the solution is a significant deterrent regardless of the size and speed of the computer system which is applied to its solution.

Another problem in the procedure requires more emphasis to be placed upon the problem grid than on easy and rapid specification of machine component sizes from a drawing. Certainly, more effort is required to reduce the tedious and time-consuming effort in establishing or significantly modifying the equivalent model of the procedure. Another aspect of this problem is that model definition in terms of polar coordinates would be preferred to the present rectangular coordinates. The significance of modification of the algorithm coordinate system is an investigation remaining to be performed.

The algorithm for this numerical analysis of electric machinery is implemented with a series of computer programs supported by a large number of functions and subroutines. The organization of programs is desirable in that progress of solution can be observed in intermediate results. The organization provides considerable amount of

error messages to guard against faulty data in parameters passed in functions or subroutines. Disadvantages of the modular organization include a difficult procedure for modifying common variables in each program and subroutine, and certain boundary conditions are imbedded in subroutine programs and add to the complexity of developing a common solution algorithm when machine configurations require modification of boundary conditions.

VI. CONCLUSION

It is concluded that algorithms implemented in Fortran programs and subroutines for the numerical solution of a homopolar-inductor alternator provide a solution of a salient-pole alternator after correction for different boundary conditions.

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APPENDIX

PRINTOUT FROM PROGRAM EXECUTION

UPDATE AND ORDER

The solution algorithm is a set of interactive Fortran programs and subroutines. In addition to a numerical analysis of a set of partial differential equations, this algorithm is a data-structure problem with programs for input, output, and inspection or modification of the data.

The printouts for several of the main programs of the analyses provide a record of the solution. The interactive nature of the program is emphasized, and the printouts supply examination of the machine configuration of the data structure and the status of progress toward the desired solution.

The program UPDATE is the main program to establish the data structure of a new configuration and to modify the structure. The printout for program UPDATE shows a modification procedure for any of 13 common variables. Prior to modification of subroutine SETUP, assignment of values to these common variables required loading and execution of a short Fortran program called PATCH.

This printout shows the use of the Fortran subroutine DATE which marks the date on the printout for modification of the data structure.

The symbol $ is teletypewriter prompting for interactive keyboard input. A zero or carriage return parameter causes another printout of the consolidated variable listing. A negative parameter causes an exit to main program from SETUP where options to change data at designated nodes of the problem grid can be exercised.

The program ORDER performs its task on the data structure without any operator input except for system commands associated with load and go.

```
THIS IS THE DISC VERSION D 18JUNE73

                         UPDATE GRID

DATE:02/ 13/ 76
IS THIS A NEW PROBLEM
$99.
OLD SIZE WAS  36 BY  29


               *PRESENT SET UP NUMBER  51*
            TYPE ONE NODE: (  52 TYPES DEFINED)
    HE       HN       HW       HS  BD.MK CUR.MK CON.MK REL.MK  MV.MK
    21       52       21       21   -34     -1     -1      1      0
                         GENERAL DATA:
UNIT LENGTH       CON5             CON7            FLUX          CURRENT
1.984375E-04 0.000000E 00 0.000000E 00 0.000000E 00 1.269000E 03
  LOCATION         BETA          MOVEMENT          TIME           TIMEB
     1              0.               0       0.000000E 00 0.000000E 00
OUTPUT.VOLTS NO.LOAD.VOLT   REACTANCE
4.000000E 01 0.000000E 00 0.000000E 00
              *                                 *


ANY CHANGES TYPE PAR NO 1 THRU 13,I3
$001

NUMP:    51 I3
$-51

ANY CHANGES TYPE PAR NO 1 THRU 13,I3
$002

AID:         1269. F10.0
$1270.

ANY CHANGES TYPE PAR NO 1 THRU 13,I3
$003

AKPHI:           0. F10.0
$0.

ANY CHANGES TYPE PAR NO 1 THRU 13,I3
$004

HRMV:            0. F10.0
$0.

ANY CHANGES TYPE PAR NO 1 THRU 13,I3
$005

DELT:            0. F10.0
$00

ANY CHANGES TYPE PAR NO 1 THRU 13,I3
$006

MORE:  1 I3
$001
```

```
ANY CHANGES TYPE PAR NO 1 THRU 13,I3
$007

CON5:          0. F10.0
$0.

ANY CHANGES TYPE PAR NO 1 THRU 13,I3
$008

CON7:          0. F10.0
$0.

ANY CHANGES TYPE PAR NO 1 THRU 13,I3
$009

ENL:         0. F10.0
$0.

ANY CHANGES TYPE PAR NO 1 THRU 13, 3
$010

VDS:        40. F10.0
$04.\
$40.

ANY CHANGES TYPE PAR NO 1 THRU 13,I3
$

                *PRESENT SET UP NUMBER   51*
             TYPE ONE NODE: (  52 TYPES DEFINED)
    HE      HN      HW      HS  BD.MK CUR.MK CON.MK REL.MK  MV.MK
    21      52      21      21    -34     -1     -1      1      0
                             GENERAL DATA:
UNIT LENGTH       CON5          CON7          FLUX         CURRENT
1.984375E-04 0.000000E 00 0.000000E 00 0.000000E 00 1.270000E 03
  LOCATION        BETA       MOVEMENT         TIME          TIMEB
       1            0.              0   0.000000E 00 0.000000E 00
OUTPUT.VOLTS NO.LOAD.VOLT   REACTANCE
4.000000E 01 0.000000E 00 0.000000E 00
              *                              *


ANY CHANGES TYPE PAR NO 1 THRU 13,I3
$011

REAC:          0. F10.0
$0.

ANY CHANGES TYPE PAR NO 1 THRU 13,I3
$012

TIME:          0. F10.0
$0.

ANY CHANGES TYPE PAR NO 1 THRU 13,I3
$013

TIMEB:          0. F10.0
$0.

ANY CHANGES TYPE PAR NO 1 THRU 13,I3
$-10
```

```
SET RANGE :
MIN MAX FOR I :
$99999
PACKING TYPES.     52
 52 TYPES DEFINED 1Ø14 TYPES AVAILABLE.
BUFFER CLEARED. SETUP RECORDED.
BUFFER CLEARED. SETUP RECORDED.
DATA SAVED ON FILE

PAUSE


SET RANGE :
MIN MAX FOR I :
$//
DATA

FORTRAN STOP
```

```
HAVE YØU CØMPILED SUBRØUTINE CUR AFTER A CHANGE IN
VARIABLE  AID?????
```

```
$//ATT,3,LT3,LCUEX,DISC
$//ATT,5,LT5,LCUEXB,DISC
$//FORT
```

LIST

The printout of program LIST consists of two parts. A modification was made to provide a brief heading to identify the problem, the date, and the grid size. The first part is a grid map that identifies nodes with grid space configuration. The first row of data identifies the width coordinate I (1 through IMAX). The first column of this part of the printout identifies the height coordinate V (VMAX through 1). This represents data of the ID matrix printed on three pages by the subroutine IDOUT.

The second printout of LIST identifies nodes with nine elements associated with every node. This output comes from ITYPE matrix and results from execution of subroutine TPOUT. Columns 2 through 10 represent elements of the nodes.

Element	Variable	Property
1	H1	Distance to Node on Right
	(Grid space 1/128 in/7.8125×10^{-3} in/1.984×10^{-4} meter)	
2	H2	Distance to Node Above
3	H3	Distance to Node to Left
4	H4	Distance to Node Below
5	BD	Boundary Mark
	(10 different variables)[3]	
6	J	Current Density – Phase Windings
7	CON	Conductivity
8	REL	Reluctivity
	(1:Air – 2:SAE 4340 Iron, rotor – 3:Armco Trancor T-Steel, stator)	
9	VEL	Material Movement Indicator
	(Different variables)[4]	

[3] A. L. Jokl and L. I. Amstutz, Report 2113, "Nonlinear Homopolar Inductor Alternators on Nonlinear Loads – Part I," USAMERDC, Fort Belvoir, VA, October 1974.

[4] *Ibid.*

THIS IS THE DISC VERSION D 13JUNE73

PROBLEM LJ 51
DATE:02/ 26/ 76

GRID SIZE 36 BY 29

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
29	50	51	51	51	51	51	51	51	51	51	51	51	51	51
28	4	5	5	5	5	5	5	5	5	5	5	5	5	5
27	4	5	5	5	5	5	5	5	5	5	5	5	5	5
26	4	49	49	49	49	49	49	49	49	49	49	49	49	49
25	46	47	47	47	47	47	47	47	47	47	47	47	47	47
24	42	43	43	44	43	43	44	43	43	44	43	43	44	43
23	38	19	39	40	19	39	40	19	39	40	19	39	40	19
22	38	19	39	40	19	39	40	19	39	40	19	39	40	19
21	38	19	39	40	19	39	40	19	39	40	19	39	40	19
20	34	35	36	36	35	36	36	35	36	36	35	36	36	35
19	30	31	31	31	31	31	31	31	32	32	32	32	32	32
18	18	25	25	25	25	25	25	19	29	15	19	29	15	19
17	18	25	25	25	25	25	26	22	22	22	22	15	15	15
16	18	25	25	25	25	25	26	21	27	27	22	15	15	15
15	18	25	25	25	25	25	26	21	27	27	22	15	15	15
14	18	25	25	25	25	25	26	21	27	27	22	15	15	15
13	18	25	25	25	25	25	26	21	27	27	22	15	15	15
12	18	25	25	25	25	25	26	21	27	27	22	15	15	15
11	18	25	25	25	25	25	26	21	27	27	22	15	15	15
10	18	25	25	25	25	25	26	21	27	27	22	15	15	15
9	18	19	19	19	19	19	20	21	21	21	22	15	15	15
8	14	15	15	15	15	15	17	17	17	17	17	15	15	15
7	14	15	15	15	15	15	15	15	15	15	15	15	15	15
6	11	12	12	12	12	12	12	12	12	12	12	12	12	12
5	7	10	10	10	10	10	10	10	10	10	10	10	10	10
4	7	8	8	8	8	8	8	8	8	8	8	8	8	8
3	4	5	5	5	5	5	5	5	5	5	5	5	5	5
2	4	5	5	5	5	5	5	5	5	5	5	5	5	5
1	1	2	2	2	2	2	2	2	2	2	2	2	2	2

	15	16	17	18	19	20	21	22	23	24	25	26	27	28
29	51	51	51	51	51	51	51	51	51	51	51	51	51	51
28	5	5	5	5	5	5	5	5	5	5	5	5	5	5
27	5	5	5	5	5	5	5	5	5	5	5	5	5	5
26	49	49	49	49	49	49	49	49	49	49	49	49	49	49
25	47	47	47	47	47	47	47	47	47	47	47	47	47	47
24	43	44	43	43	44	43	43	44	43	43	44	43	43	44
23	39	40	19	39	40	19	39	40	19	39	40	19	39	40
22	39	40	19	39	40	19	39	40	19	39	40	19	39	40
21	39	40	19	39	40	19	39	40	19	39	40	19	39	40
20	36	36	35	36	36	35	36	36	35	36	36	35	36	36
19	32	32	32	32	32	32	32	32	32	32	32	32	32	32
18	29	15	19	29	15	19	29	15	19	29	15	19	29	15
17	15	15	15	15	15	15	15	15	15	15	15	17	22	22
16	15	15	15	15	15	15	15	15	15	15	15	17	23	28
15	15	15	15	15	15	15	15	15	15	15	15	17	23	28
14	15	15	15	15	15	15	15	15	15	15	15	17	23	28
13	15	15	15	15	15	15	15	15	15	15	15	17	23	28
12	15	15	15	15	15	15	15	15	15	15	15	17	23	28
11	15	15	15	15	15	15	15	15	15	15	15	17	23	28
10	15	15	15	15	15	15	15	15	15	15	15	17	23	28
9	15	15	15	15	15	15	15	15	15	15	15	17	23	23
8	15	15	15	15	15	15	15	15	15	15	15	17	17	17
7	15	15	15	15	15	15	15	15	15	15	15	15	15	15
6	12	12	12	12	12	12	12	12	12	12	12	12	12	12
5	10	10	10	10	10	10	10	10	10	10	10	10	10	10
4	8	8	8	8	8	8	8	8	8	8	8	8	8	8
3	5	5	5	5	5	5	5	5	5	5	5	5	5	5
2	5	5	5	5	5	5	5	5	5	5	5	5	5	5
1	2	2	2	2	2	2	2	2	2	2	2	2	2	2

	29	30	31	32	33	34	35	36
29	51	51	51	51	51	51	51	52
28	5	5	5	5	5	5	5	6
27	5	5	5	5	5	5	5	6
26	49	49	49	49	49	49	49	6
25	47	47	47	47	47	47	47	48
24	43	43	44	43	43	44	43	45
23	19	39	40	19	39	40	19	41
22	19	39	40	19	39	40	19	41
21	19	39	40	19	39	40	19	41
20	35	36	36	35	36	36	35	37
19	32	31	31	31	31	31	31	33
18	19	19	25	25	25	25	25	24
17	22	20	25	25	25	25	25	24
16	28	20	25	25	25	25	25	24
15	28	20	25	25	25	25	25	24
14	28	20	25	25	25	25	25	24
13	28	20	25	25	25	25	25	24
12	28	20	25	25	25	25	25	24
11	28	20	25	25	25	25	25	24
10	28	20	25	25	25	25	25	24
9	23	20	19	19	19	19	19	24
8	17	17	15	15	15	15	15	16
7	15	15	15	15	15	15	15	16
6	12	12	12	12	12	12	12	13
5	10	10	10	10	10	10	10	9
4	8	8	8	8	8	8	8	9
3	5	5	5	5	5	5	5	6
2	5	5	5	5	5	5	5	6
1	2	2	2	2	2	2	2	3

#	H1	H2	H3	H4	BD	J	CON	REL	VEL
1	21	52	21	21	-34	-1	-1	1	0
2	21	52	21	21	-4	-1	-1	1	0
3	21	52	21	21	-41	-1	-1	1	0
4	21	52	21	52	-3	-1	-1	1	0
5	21	52	21	52	0	-1	-1	1	0
6	21	52	21	52	-1	-1	-1	1	0
7	21	52	21	52	-3	-1	-1	2	0
8	21	52	21	52	1	-1	-1	2	0
9	21	52	21	52	-1	-1	-1	2	0
10	21	52	21	52	0	-1	-1	2	0
11	21	21	21	52	-3	-1	-1	2	0
12	21	21	21	52	0	-1	-1	2	0
13	21	21	21	52	-1	-1	-1	2	0
14	21	21	21	21	-3	-1	-1	2	0
15	21	21	21	21	0	-1	-1	2	0
16	21	21	21	21	-1	-1	-1	2	0
17	21	21	21	21	0	0	-1	2	0
18	21	21	21	21	-3	-1	-1	1	0
19	21	21	21	21	1	-1	-1	1	0
20	21	21	21	21	1	0	-1	1	0
21	21	21	21	21	1	6	-1	1	0
22	21	21	21	21	1	0	-1	2	0
23	21	21	21	21	1	-6	-1	1	0
24	21	21	21	21	-1	-1	-1	1	0
25	21	21	21	21	0	-1	-1	1	0
26	21	21	21	21	0	0	-1	1	0
27	21	21	21	21	0	6	-1	1	0
28	21	21	21	21	0	-6	-1	1	0
29	21	21	21	21	1	-1	-1	2	0
30	21	6	21	21	-3	-1	-1	1	0
31	21	6	21	21	0	-1	-1	1	0
32	21	6	21	21	1	-1	-1	1	0
33	21	6	21	21	-1	-1	-1	1	0
34	21	21	21	6	-3	-1	-1	3	0
35	21	21	21	6	1	-1	-1	1	0
36	21	21	21	6	1	-1	-1	3	0
37	21	21	21	6	-1	-1	-1	3	0
38	21	21	21	21	-3	-1	-1	3	0
39	21	21	21	21	1	-1	-1	3	0
40	21	21	21	21	0	-1	-1	3	0
41	21	21	21	21	-1	-1	-1	3	0
42	21	52	21	21	-3	-1	-1	3	0
43	21	52	21	21	1	-1	-1	3	0
44	21	52	21	21	0	-1	-1	3	0
45	21	52	21	21	-1	-1	-1	3	0
46	21	52	21	52	-3	-1	-1	3	0
47	21	52	21	52	0	-1	-1	3	0
48	21	52	21	52	-1	-1	-1	3	0
49	21	52	21	52	1	-1	-1	1	0
50	21	21	21	52	-23	-1	-1	1	0
51	21	21	21	52	-2	-1	-1	1	0
52	21	21	21	52	-12	-1	-1	1	0
#	H1	H2	H3	H4	BD	J	CON	REL	VEL

MAP

Printouts for program MAP and several MAP subroutines provide six separate maps:

1. Boundary Map
2. Conductivity Map
3. Rotor Movement Map
4. Iron Map
5. Current Map
6. Dimensions Check Map

The negative problem number in the heading of the map is an indicator that a subsequent program START needs to be executed. It is noted that all six maps are made even though no useful information is provided in two maps. These maps provide the major comparison of the data structure and the simulation model specifications.

The boundary map depicts external boundaries with an E and internal boundaries or material changes with a B. The model shown, using air space above the stator and below the rotor, was intended to provide zero flux through stator-air interface above and zero flux through rotor-air interface below. This was an effort to provide the horizontal boundaries with configuration of the model rather than changing to software boundary conditions. The primary disadvantage is that grid locations in these air spaces require execution time and, perhaps, solution stability problems with larger numbers of grid points.

The conductivity map and the rotor movement map contain no useful information in this example.

In the iron map, S indicates SAE 4340 iron in the rotor and T indicates Trancor T steel in the stator. A blank indicates air.

The field current in the rotor coil is indicated with A and X on the current map. The machine was investigated for no load so no currents are shown for stator currents. The stars, or asterisks, provide information related to summation of currents at nodes adjacent to the coil.

The dimensions check map checks for consistent node spacing between the grid nodes. If all spaces are consistent, the entire map is blank except for coordinate symbols at head, left side, and bottom of map. An asterisk is an indication for a dimension error. An error in this example occurred in rows 1 and 29 because distance to node above, H2, and distance to node below, H4, were unequal values.

BOUNDARY MAP   LOCATION = 1   PROBLEM LJ -51

```
             111111111122222222223333333
    123456789012345678901234567890123456
 29 EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
 28 E                                  E
 27 E                                  E
 26 EBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBE
 25 E                                  E
 24 EBB BB BB BB BB BB BB BB BB BB BB BE
 23 EBB BB BB BB BB BB BB BB BB BB BB B
 22 EBB BB BB BB BB BB BB BB BB BB BB B
 21 EBB BB BB BB BB BB BB BB BB BB BB B
 20 EBBBBBBBBBBBBBBBBBBBBBBBBB B  B  B E
 19 E       BBBBBBBBBBBBBBBB B  B       E
 18 E      BB BB BB BB BB BB BB BB     E
 17 E      BBBB               BBBB     E
 16 E      B  B               B  B     E
 15 E      B  B               B  B     E
 14 E      B  B               B  B     E
 13 E      B  B               B  B     E
 12 E      B  B               B  B     E
 11 E      B  B               B  B     E
 10 E      B  B               B  B     E
  9 EBBBBBBBBBB               BBBBBBBBB
  8 E
  7 E
  6 E
  5 E                                  E
  4 EBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBE
  3 E
  2 E                                  E
  1 EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
             111111111122222222223333333
    123456789012345678901234567890123456
```

```
                     11        11     1111       111      1111  1 1111   1 1111

     CONDUCTIVITY MAP       LOCATION = 1     PROBLEM LJ   -51

             1111111111222222222233333333
    123456789012345678901234567890123456
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
 9
 8
 7
 6
 5
 4
 3
 2
 1
             1111111111222222222233333333
    123456789012345678901234567890123456
```

```
ROTOR MOVEMENT MAP     LOCATION = 1     PROBLEM LJ  -51

                   11111111112222222222333333
          123456789012345678901234567890123456
        29
        28
        27
        26
        25
        24
        23
        22
        21
        20
        19
        18
        17
        16
        15
        14
        13
        12
        11
        10
         9
         8
         7
         6
         5
         4
         3
         2
         1
                   11111111112222222222333333
          123456789012345678901234567890123456
```

```
IRON MAP        LOCATION = 1      PROBLEM LJ  -51

             111111111122222222223333333
    123456789012345678901234567890123456
 29
 28
 27
 26
 25 TTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTT
 24 TTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTT
 23 T TT TT TT TT TT TT TT TT TT TT TT T
 22 T TT TT TT TT TT TT TT TT TT TT TT T
 21 T TT TT TT TT TT TT TT TT TT TT TT T
 20 T TT TT TT TT TT TT TT TT TT TT TT T
 19
 18         SS SS SS SS SS SS SS
 17        SSSSSSSSSSSSSSSSSSSSSS
 16           SSSSSSSSSSSSSSSS
 15           SSSSSSSSSSSSSSSS
 14           SSSSSSSSSSSSSSSS
 13           SSSSSSSSSSSSSSSS
 12           SSSSSSSSSSSSSSSS
 11           SSSSSSSSSSSSSSSS
 10           SSSSSSSSSSSSSSSS
  9           SSSSSSSSSSSSSSSS
  8 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
  7 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
  6 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
  5 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
  4 SSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
  3
  2
  1

             111111111122222222223333333
    123456789012345678901234567890123456
```

CURRENT MAP   LOCATION = 1   PROBLEM LJ -51

```
            1111111111222222222233333333
   123456789012345678901234567890123456
29
28
27
26
25
24
23
22
21
20
19
18
17       *****              *****
16       *AAA*              *XXX*
15       *AAA*              *XXX*
14       *AAA*              *XXX*
13       *AAA*              *XXX*
12       *AAA*              *XXX*
11       *AAA*              *XXX*
10       *AAA*              *XXX*
 9       *AAA*              *XXX*
 8       *****              *****
 7
 6
 5
 4
 3
 2
 1
            1111111111222222222233333333
   123456789012345678901234567890123456
```

```
DIMENSIONS CHECK       LOCATION = 1     PROBLEM LJ  -51

                 111111111122222222223333333
        123456789012345678901234567890123456
     29 ************************************
     28
     27
     26
     25
     24
     23
     22
     21
     20
     19
     18
     17
     16
     15
     14
     13
     12
     11
     10
      9
      8
      7
      6
      5
      4
      3
      2
      1 ************************************
                 111111111122222222223333333
        123456789012345678901234567890123456
```

START AND SOLVE

The program START takes the configuration specification which has been input and checked by previous programs and provides an initial solution to magnetic vector potentials in the A matrix. After loading, an input on the keyboard of the negative value of problem number performs the initialization calculations. The problem number is changed to a positive value as the indication that this program was executed.

The next output comes from execution of the program SOLVE. This output indicates that the conditions for solution were reached after iteration 149.

The conditions of solution were achieved, but the number of iterations is wrong. A previous execution of SOLVE went through an estimated 100 iterations prior to this run. This procedure provides an analysis much closer to the acceptable solution than that provided by Program START. The reloading and restarting of SOLVE execution were required to retain table of Beta values which depends on logic path where the value of Flux is equal to the maximum and minimum value of the vector magnetic potentials. The Beta values of 50 are used as keys to subroutines to recalculate the reluctivities.

Printout of asterisk and period provides location pointers at the beginning of the program SOLVE. During the interval between the asterisk and period, the algorithm provides a real variable printout of Beta. If the Beta printout is zero, a recalculation of reluctivities is not done. If Beta is 50, then a recalculation of reluctivities is done and the parameters of subroutine RELSET are printed out. It was noted later that this parameter listing duplicates information shown in the 5-line printout for each iteration.

Subroutine RELSET parameters are:

PREV, PSREV, IIDR, IISDR, NNDR, NNSDR, MXI, MXJ.

The 5-line printout for each iteration is described in the chart:

Line 1

1.	ITER	Iteration Number
2.	RMAX	Maximum Residual
3.	RMSR	RMS Residual
4.	CCR	Ave value of $\lvert R \rvert$
5.	NNSDR N	% of nodes that $\lvert DR \rvert \geqslant 0.05$ RELSET
6.	NNDR	% of nodes that $\lvert DR \rvert \leqslant 0.05$

Line 2		
1.	(IMR,	Coordinate of RMAX
2.	JMR)	Coordinate of RMAX
3.	IISDR V	Ave value of nodes that $\lvert DR \rvert \geqslant 0.05$ RELSET
4.	IIDR	Ave value of nodes that $\lvert DR \rvert < 0.05$
Line 3		
1.	(IMRE,	Coordinate of RMAXE
2.	JMRE)	Coordinate of RMAXE
3.	(IMDRR,	Coordinate of $\lvert DR \rvert$ max RELSET
4.	JMDRR)	Coordinate of $\lvert DR \rvert$ max
Line 4		
1.	(IMR,	
2.	JMR)	
3.	GOAL	
Line 5		
1.	RMAXE	Maximum Residual
2.	RMSRE	RMS Residual
3.	CCRE	Ave value of $\lvert R \rvert$
4.	DELMAX	
5.	RMSDEL	
6.	CCDEL	
7.	IOSR/PSREV R	% of sign reversals $\lvert DR \rvert < 0.05$ RELSET
8.	IOR/PREV	% of sign reversals above saturation
9.	NCOND	
10.	NAPPL	
11.	IOB/BETA	Beta = TDB (I, 2)
12.	EDDY	
13.	IPTDB	

```
$//ABSD,15,120,65140,1000
$//REW,14
$//REW,15
$//ABSL,14
$//GO
THIS IS THE DISC VERSION D 18JUNE73
RESTART
$999
RECALCULATE RELUCTIVITIES
$000
ENTER ITERATION LIMIT
$ 10
PRINT EVERY STEP
$

ITER  RMAX    RRMS    RCCR    DMAX    DRMS   DCCC    REL   OK BA  B UB.E.C. PT

FLUX    .978599E-01
*

   0.00

  45.01   39.90   2   72    7  92   27  25

.
 -2 1.E 02 2.E 01 6.E 00
   ( 1,10)                                           92N 7
   ( 1, 9)                                           72V 2
                                                    (27,25)
                                ( 3,24) 1.E-03
    6.E-05 7.E-06 3.E-06 3.E-04 2.E-04 1.E-04 39R45   1   1    0 0.E 00  1
*

   0.00

.
 -1 2.E 02 2.E 01 6.E 00
   ( 1,11)                                           92N 7
   ( 1,24)                                           72V 2
                                                    ( 0, 0)
                                ( 1,24) 1.E-03
    2.E-04 1.E-05 4.E-06 6.E-04 3.E-04 2.E-04 39R45   0   0   50 0.E 00  2
*

  50.00

  44.66   40.05   1   75    6  93   27  25

.
  0 7.E 02 9.E 01 3.E 01
   (28,25)                                           93N 6
   (13,24)                                           75V 1
                                                    (27,25)
                                (28,25) 2.E-04
    1.E-02 1.E-03 3.E-04 4.E-02 5.E-03 1.E-03 40R44   0   1    0 0.E 00  3
*

   0.00

.
  1 3.E 02 4.E 01 2.E 01
   (27,26)                                           93N 6
   (36,25)                                           75V 1
                                                    ( 0, 0)
                                ( 2,25) 2.E-04
    2.E-03 1.E-04 4.E-05 5.E-03 8.E-04 5.E-04 40R44   0   2    0 0.E 00  3
```

```
*

  0.00

 •
 2 3.E 02 4.E 01 1.E 01                                  93N 6
  ( 1,10)                                                75V 1
  (13, 6)                                               ( 0, 0)
                         (13, 6) 2.E-04
   9.E-04 8.E-05 3.E-05 2.E-03 4.E-04 2.E-04 40R44   0  3    0 0.E 00  3
*

  0.00

 •
 3 2.E 02 3.E 01 1.E 01                                  93N 6
  ( 1,10)                                                75V 1
  ( 2,25)                                               ( 0, 0)
                         ( 2,25) 2.E-04
   3.E-04 3.E-05 2.E-05 6.E-04 1.E-04 6.E-05 40R44   1  3    0 0.E 00  3
*

  0.00

 22.25    19.50    2   68   11   89   25   22

 •
 4 1.E 02 2.E 01 7.E 00                                  89N11
  (36,12)                                                68V 2
  (36,25)                                               (25,22)
                         (36,25) 2.E-04
   1.E-04 9.E-06 5.E-06 2.E-04 6.E-05 4.E-05 19R22   0  0   50 0.E 00  4
*

 50.00

 22.25    19.50    2   68   11   88   25   22

 •
 5 7.E 02 9.E 01 3.E 01                                  88N11
  (35,24)                                                68V 2
  (25,21)                                               (25,22)
                         ( 5,25) 1.E-04
   7.E-03 1.E-03 3.E-04 3.E-02 4.E-03 1.E-03 19R22   0  1    0 0.E 00  4
*

  0.00

 •
 6 1.E 03 8.E 01 2.E 01                                  88N11
  (22,20)                                                68V 2
  ( 1,25)                                               ( 0, 0)
                         ( 1,25) 1.E-04
   4.E-03 2.E-04 7.E-05 8.E-03 8.E-04 3.E-04 19R22   0  2    0 0.E 00  4
*

  0.00

 •
 7 2.E 02 2.E 01 1.E 01                                  88N11
  (35,25)                                                68V 2
  (35,25)                                               ( 0, 0)
                         (35,25) 1.E-04
   2.E-03 9.E-05 3.E-05 3.E-03 3.E-04 2.E-04 19R22   0  3    0 0.E 00  4
```

```
*

  0.00

 8 2.E 02 2.E 01 8.E 00                                 88N11
  (36,10)                                               68V 2
  ( 2,25)                                              ( 0, 0)
                          (35,25) 1.E-04
  6.E-04 4.E-05 1.E-05 1.E-03 2.E-04 2.E-04 19R22   0   3    0 0.E 00   4
*

  0.00

 38.84    35.35   2   63   10   89   21   21

 9 2.E 02 2.E 01 7.E 00                                 89N10
  (36,10)                                               63V 2
  ( 2,25)                                              (21,21)
                          ( 2,25) 1.E-04
  4.E-04 3.E-05 1.E-05 1.E-03 8.E-05 4.E-05 35R38   1   3    0 0.E 00   4
*

  0.00

10 9.E 01 1.E 01 6.E 00                                 89N10
  (35,10)                                               63V 2
  (35,25)                                              ( 0, 0)
                          ( 4,24) 1.E-04
  1.E-04 8.E-06 4.E-06 9.E-04 3.E-04 2.E-04 35R38   0   3    0 0.E 00   4
ITERATION LIMIT. DUMP & RELOAD TO CONTINUE
BUFFER CLEARED. SETUP RECORDED.
DATA WRITTEN ON TAPE
THIS IS THE DISC VERSION D 18JUNE73

FORTRAN STOP
$//ABSD,15,120,65140,1000
$//REW,14
$//REW,15
$//ABSL,14
$//GO
THIS IS THE DISC VERSION D 18JUNE73
RESTART
$000
ENTER ITERATION LIMIT
$020
PRINT EVERY STEP.
$000

ITER  RMAX   RRMS   RCCR   DMAX   DRMS   DCCC   REL   OK BA  B UB.E.C. PT
*

  0.00

11 3.E 02 3.E 01 7.E 00                                 89N10
  ( 1,10)                                               63V 2
  ( 1,23)                                              ( 0, 0)
                          ( 1,22) 1.E-04
  2.E-04 2.E-05 6.E-06 4.E-04 1.E-04 1.E-04 35R38   1   3    0 0.E 00   4
```

```
*
  0.00
 39.21    35.50   2  66   8  91  16  24
.
12 2.E 02 2.E 01 6.E 00                        91N 8
   (36,10)                                     66V 2
   ( 7,24)                                    (16,24)
                          (36,12) 1.E-04
   8.E-05 1.E-05 5.E-06 2.E-04 4.E-05 3.E-05 35R39  0  0  50 0.E 00  5
*
  50.00
 39.07    35.58   2  66   8  91  16  24
.
13 3.E 02 5.E 01 2.E 01                        91N 8
   (33,25)                                     66V 2
   (16,24)                                    (16,24)
                          ( 3,25) 1.E-04
   8.E-03 8.E-04 2.E-04 2.E-02 3.E-03 7.E-04 35R39  0  1   0 0.E 00  5
*
  0.00
 26.17    22.82   1  53  12  87  15  23
.
14 4.E 02 3.E 01 1.E 01                        87N12
   (16,20)                                     53V 1
   (35,25)                                    (15,23)
                          ( 1,25) 1.E-04
   3.E-03 1.E-04 3.E-05 6.E-03 4.E-04 1.E-04 22R26  0  2   0 0.E 00  5
*
  0.00
 28.57    24.33   2  56  15  84  18  24
.
15 1.E 02 2.E 01 8.E 00                        84N15
   ( 1,28)                                     56V 2
   (35,25)                                    (18,24)
                          (35,25) 1.E-04
   1.E-03 6.E-05 1.E-05 3.E-03 2.E-04 7.E-05 24R28  1  3   0 0.E 00  5
*
  0.00
 28.35    24.55   1  55  12  87  18  24
.
16 1.E 02 2.E 01 7.E 00                        87N12
   (36,10)                                     55V 1
   ( 2,25)                                    (18,24)
                          ( 2,25) 1.E-04
   3.E-04 2.E-05 6.E-06 5.E-04 9.E-05 7.E-05 24R28  0  0  50 0.E 00  6
*
  50.00
 28.51    24.28   1  56  13  86  18  24
.
17 3.E 02 4.E 01 1.E 01                        86N13
   (19,23)                                     56V 1
   (19,24)                                    (18,24)
                          ( 4,25) 1.E-04
   6.E-03 5.E-04 1.E-04 9.E-03 1.E-03 4.E-04 24R28  0  1   0 0.E 00  6
```

```
*

   0.00

.
 18 1.E 02 3.E 01 1.E 01                              86N13
   ( 1,10)                                            56V 1
   (22,24)                                           ( 0, 0)
                         (22,24) 1.E-04
    4.E-03 3.E-04 6.E-05 6.E-03 6.E-04 2.E-04 24R28  0  2   0 0.E 00  6
*

   0.00

.
 19 9.E 01 1.E 01 6.E 00                              86N13
   (35,27)                                            56V 1
   ( 1,25)                                           ( 0, 0)
                         (35,25) 1.E-04
    5.E-04 2.E-05 6.E-06 1.E-03 2.E-04 2.E-04 24R28  0  3   0 0.E 00  6
*

   0.00

.
 20 2.E 02 2.E 01 7.E 00                              86N13
   (36,27)                                            56V 1
   ( 2,25)                                           ( 0, 0)
                         ( 2,25) 1.E-04
    2.E-04 2.E-05 6.E-06 3.E-04 8.E-05 6.E-05 24R28  1  3   0 0.E 00  6
 ITERATION LIMIT. DUMP & RELOAD TO CONTINUE
BUFFER CLEARED. SETUP RECORDED.
DATA WRITTEN ON TAPE
THIS IS THE DISC VERSION D 18JUNE73

FORTRAN STOP
$//ABSD,15,120,65140,1000
$//REW,14
$//REW,15
$//ABSL,14
$//GO
THIS IS THE DISC VERSION D 18JUNE73
RESTART
$000
ENTER ITERATION LIMIT
$050
PRINT EVERY STEP
$000


ITER  RMAX   RRMS   RCCR   DMAX   DRMS  DCCC   REL  OK BA  B UB.E.C. PT
 *

   0.00

 26.55   20.13   1  40  16  83  19  24

.
 21 1.E 02 2.E 01 6.E 00                              83N16
   (36,29)                                            40V 1
   (34,24)                                           (19,24)
                         ( 2,25) 1.E-04
    9.E-05 1.E-05 4.E-06 2.E-04 3.E-05 2.E-05 20R26  0  0  50 0.E 00  7
```

```
*
 50.00

 26.77   20.13   2  41  17  82  19  24
.
22 2.E 02 2.E 01 9.E 00                               82N17
   (19,23)                                            41V 2
   (19,24)                                           (19,24)
                           (19,24) 9.F-05
    6.E-03 4.E-04 6.E-05 8.E-03 6.E-04 2.E-04 20R26  0  1   0 0.E 00  7
*
   0.00
.
23 1.E 02 1.E 01 6.E 00                               82N17
   ( 1,27)                                            41V 2
   (18,25)                                           ( 0, 0)
                           (18,25) 9.E-05
    2.E-03 9.E-05 1.E-05 3.E-03 2.E-04 7.E-05 20R26  1  2   0 0.E 00  7
*
   0.00

 16.26   11.36   2  30  16  83  19  22
.
24 1.E 02 2.E 01 6.E 00                               83N16
   (36,27)                                            30V 2
   (17,25)                                           (19,22)
                           (17,25) 9.E-05
    5.E-04 2.E-05 6.E-06 6.E-04 5.E-05 4.E-05 11R16  0  0  50 0.E 00  8
*
  50.00

 16.04   10.91   2  30  17  82  19  22
.
25 1.E 02 2.E 01 7.E 00                               82N17
   (19,23)                                            30V 2
   (19,24)                                           (19,22)
                           (19,24) 8.E-05
    3.E-03 2.E-04 3.E-05 3.E-03 3.E-04 1.E-04 10R16  0  1   0 0.E 00  8
*
   0.00
.
26 2.E 02 2.E 01 6.E 00                               82N17
   ( 1,27)                                            30V 2
   (19,22)                                           ( 0, 0)
                           (19,22) 8.F-05
    1.E-03 7.E-05 1.E-05 2.E-03 2.E-04 1.E-04 10R16  0  2   0 0.E 00  8
*
   0.00
.
27 3.E 02 2.E 01 7.E 00                               82N17
   (19,20)                                            30V 2
   (18,25)                                           ( 0, 0)
                           (18,25) 8.E-05
    1.E-03 4.E-05 9.E-06 1.E-03 7.E-05 3.E-05 10R16  1  3   0 0.E 00  8
```

```
*

  0.00

.
 28 1.E 02 1.E 01 5.E 00                              82N17
   (36,29)                                            30V 2
   ( 2,25)                                            ( 0, 0)
                              (20,18) 8.E-05
   4.E-05 5.E-06 3.E-06 3.E-04 1.E-04 1.E-04 10R16  0  3    0 0.E 00  8
*

  0.00

.
 29 2.E 02 2.E 01 5.E 00                              82N17
   (36,27)                                            30V 2
   (25,24)                                            ( 0, 0)
                              (17,17) 8.E-05
   5.E-05 7.E-06 3.E-06 2.E-04 7.E-05 6.E-05 10R16  1  3    0 0.E 00  8
*

  0.00

.
 30 1.E 02 2.E 01 5.E 00                              82N17
   ( 1,27)                                            30V 2
   ( 1, 9)                                            ( 0, 0)
                              ( 1, 9) 8.E-05
   4.E-05 6.E-06 3.E-06 1.E-04 3.E-05 2.E-05 10R16  0  0   50 0.E 00  9
*

 50.00

 10.94     7.81    1  25   17  82   18  23

.
 31 1.E 02 1.E 01 6.E 00                              82N17
   ( 1,29)                                            25V 1
   (19,24)                                            (18,23)
                              (33,25) 7.E-05
   9.E-04 7.E-05 2.E-05 2.E-03 3.E-04 8.E-05  7R10  0  1    0 0.E 00  9
*

  0.00

.
 32 1.E 02 1.E 01 5.E 00                              82N17
   (36,26)                                            25V 1
   (36,25)                                            ( 0, 0)
                              (36,25) 7.E-05
   4.E-04 2.E-05 4.E-06 7.E-04 6.E-05 4.E-05  7R10  1  2    0 0.E 00  9
*

  0.00

.
 33 1.E 02 1.E 01 5.E 00                              82N17
   (36,27)                                            25V 1
   ( 2,25)                                            ( 0, 0)
                              ( 2,25) 7.E-05
   2.E-04 7.E-06 3.E-06 3.E-04 4.E-05 3.E-05  7R10  0  0   50 0.E 00 10
```

```
*

 50.00

 14.73   10.71   2  25  20  79  19  24

34 1.E 02 2.E 01 6.E 00                           79N2 0
  ( 1,27)                                         25V 2
  ( 5,25)                                        (19,24)
                          ( 5,25) 6.E-05
   5.E-04 6.E-05 2.E-05 3.E-03 3.E-04 1.E-04 10R14  0  1    0 0.E 00 10
*

  0.00

35 1.E 02 2.E 01 5.E 00                           79N2 0
  ( 1,27)                                         25V 2
  ( 1,25)                                        ( 0, 0)
                          ( 1,25) 6.E-05
   4.E-04 3.E-05 7.E-06 9.E-04 1.E-04 1.E-04 10R14  0  2    0 0.E 00 10
*

  0.00

36 2.E 02 2.E 01 5.E 00                           79N2 0
  (36,27)                                         25V 2
  (34,24)                                        ( 0, 0)
                          ( 2,25) 6.E-05
   1.E-04 1.E-05 5.E-06 3.E-04 3.E-05 2.E-05 10R14  1  3    0 0.E 00 10
*

  0.00

37 1.E 02 1.E 01 4.E 00                           79N2 0
  (36,29)                                         25V 2
  (36,25)                                        ( 0, 0)
                          (15,23) 6.E-05
   4.E-05 4.E-06 2.E-06 3.E-04 1.E-04 1.E-04 10R14  0  3    0 0.E 00 10
*

  0.00

38 2.E 02 2.E 01 5.E 00                           79N2 0
  ( 1,27)                                         25V 2
  ( 1,26)                                        ( 0, 0)
                          ( 1,26) 6.E-05
   5.E-05 6.E-06 3.E-06 2.E-04 6.E-05 5.E-05 10R14  1  3    0 0.E 00 10
*

  0.00

39 1.E 02 1.E 01 4.E 00                           79N2 0
  ( 1,27)                                         25V 2
  ( 1,24)                                        ( 0, 0)
                          (35,26) 6.E-05
   4.E-05 5.E-06 2.E-06 1.E-04 2.E-05 1.E-05 10R14  0  0   50 0.E 00 11
```

```
*
  50.00

  25.45    15.63   1  22  20  79   5  25
.
 40 9.E 01 1.E 01 4.E 00                              79N20
   (36,29)                                            22V 1
   (20,25)                                           ( 5,25)
                              ( 6,25) 5.E-05
    3.E-04 3.E-05 9.E-06 1.E-03 2.E-04 5.E-05 15R25  1  1   0 0.E 00 11
*
   0.00
.
 41 9.E 01 1.E 01 4.E 00                              79N20
   (36,27)                                            22V 1
   ( 2,25)                                           ( 0, 0)
                              ( 2,25) 5.E-05
    1.E-04 7.E-06 3.E-06 2.E-04 4.E-05 3.E-05 15R25  0  0  50 0.E 00 12
*
  50.00

  13.39     9.15   1  13  27  72   2  24
.
 42 1.E 02 1.E 01 4.E 00                              72N27
   ( 1,27)                                            13V 1
   (20,25)                                           ( 2,24)
                              ( 3,25) 4.E-05
    2.E-04 1.E-05 5.E-06 3.E-04 4.E-05 3.E-05  9R13  1  1   0 0.E 00 12
*
   0.00
.
 43 9.E 01 1.E 01 4.E 00                              72N27
   ( 1,27)                                            13V 1
   (13,18)                                           ( 0, 0)
                              (35,25) 4.E-05
    4.E-05 4.E-06 2.E-06 1.E-04 5.E-05 4.E-05  9R13  0  0  50 0.E 00 13
BUFFER CLEARED. SETUP RECORDED.
DATA WRITTEN ON TAPE
THIS IS THE DISC VERSION D 18JUNE73

FORTRAN STOP
$//ABSD,15,120,65140,1000
$RESETTING SYSTEM
$//RESET
RESETTING SYSTEM
$//ATT,4,TTY
$//ATT,14,LT7,RELOAD,DISC 25 FEB 76
$//ATT,15,LT8,RELOAD,DISC
$//ABSL,14
$//GO
THIS IS THE DISC VERSION D 18JUNE73
RESTART
$000
ENTER ITERATION LIMIT
$100
PRINT EVERY STEP
$
```

```
ITER  RMAX   RRMS   RCCR   DMAX   DRMS  DCCC   REL  OK BA  B UB.E.C. PT
*

  50.00

  8.26     .67   1  11  28  71  14  25

.
 44 1.E 02 1.E 01 4.E 00                          71N28
   (36,27)                                        11V 1
   ( 2,25)                                       (14,25)
                            ( 2,25) 4.E-05
    9.E-05 9.E-06 4.E-06 3.E-04 8.E-05 7.E-05  ØR 3  Ø  1    Ø Ø.E ØØ 13
*

  Ø.ØØ

.
 45 1.E Ø2 1.E Ø1 4.E ØØ                          71N28
   (36,28)                                        11V 1
   (14,17)                                       ( Ø, Ø)
                            (36,25) 4.E-Ø5
    6.E-Ø5 6.E-Ø6 3.E-Ø6 1.E-Ø4 2.E-Ø5 1.E-Ø5  ØR 8  1  2    Ø Ø.E ØØ 13
*

  Ø.ØØ

.
 46 7.E Ø1 8.E ØØ 3.E ØØ                          71N28
   ( 1,29)                                        11V 1
   ( 1,25)                                       ( Ø, Ø)
                            (27, 9) 4.E-Ø5
    2.E-Ø5 3.E-Ø6 1.E-Ø6 2.E-Ø4 1.E-Ø4 9.E-Ø5  ØR 8  Ø  3    Ø Ø.E ØØ 13
*

  Ø.ØØ

.
 47 1.E Ø2 1.E Ø1 4.E ØØ                          71N28
   ( 1,27)                                        11V 1
   ( 1,24)                                       ( Ø, Ø)
                            ( 1,24) 4.E-Ø5
    7.E-Ø5 5.E-Ø6 2.E-Ø6 2.E-Ø4 4.E-Ø5 3.E-Ø5  ØR 8  1  3    Ø Ø.E ØØ 13
*

  Ø.ØØ

.
 48 9.E Ø1 1.E Ø1 3.E ØØ                          71N28
   (36,27)                                        11V 1
   (36, 9)                                       ( Ø, Ø)
                            (36, 9) 4.E-Ø5
    3.E-Ø5 4.E-Ø6 2.E-Ø6 7.E-Ø5 2.E-Ø5 1.E-Ø5  ØR 8  Ø  Ø   5Ø Ø.E ØØ 14
*

  5Ø.ØØ

  10.49    3.57   1  11  23  76  19  18

.
 49 7.E Ø1 7.E ØØ 3.E ØØ                          76N23
   (36,29)                                        11V 1
   (36,25)                                       (19,18)
                            (33,25) 3.E-Ø5
    5.E-Ø5 7.E-Ø6 3.E-Ø6 3.E-Ø4 3.E-Ø5 2.E-Ø5  3R1Ø  1  1    Ø Ø.E ØØ 14
```

```
*

  0.00

50 6.E 01 7.E 00 3.E 00                                  76N2 3
  ( 1,29)                                                11V 1
  ( 1,25)                                                ( 0, 0)
                                    (35, 9) 3.E-05
   4.E-05 3.E-06 2.E-06 6.E-05 3.E-05 2.E-05  3R10  0  0  50 0.E 00 15
*

 50.00

  8.48    3.79   1  10  27  72   2  24

51 7.E 01 8.E 00 3.E 00                                  72N2 7
  ( 1,27)                                                10V 1
  ( 3,25)                                                ( 2,24)
                                    ( 3,25) 3.E-05
   7.E-05 7.E-06 3.E-06 3.E-04 4.E-05 2.E-05  3R 8  1  1   0 0.E 00 15
*

  0.00

52 6.E 01 7.E 00 3.E 00                                  72N2 7
  (36,29)                                                10V 1
  (36,25)                                                ( 0, 0)
                                    (36,25) 3.E-05
   4.E-05 3.E-06 2.E-06 1.E-04 4.E-05 3.E-05  3R 8  0  2   0 0.E 00 15
*

  0.00

53 7.E 01 8.E 00 3.E 00                                  72N2 7
  (36,27)                                                10V 1
  (28,24)                                                ( 0, 0)
                                    ( 7,24) 3.E-05
   3.E-05 3.E-06 1.E-06 1.E-04 7.E-05 6.E-05  3R 8  0  3   0 0.E 00 15
*

  0.00

54 8.E 01 9.E 00 3.E 00                                  72N2 7
  ( 1,27)                                                10V 1
  ( 1,23)                                                ( 0, 0)
                                    ( 1, 9) 3.E-05
   3.E-05 3.E-06 1.E-06 7.E-05 1.E-05 8.E-06  3R 8  1  3   0 0.E 00 15
*

  0.00

55 6.E 01 6.E 00 2.E 00                                  72N2 7
  ( 1,29)                                                10V 1
  ( 1,29)                                                ( 0, 0)
                                    (33,22) 3.E-05
   2.E-05 2.E-06 1.E-06 2.E-04 9.E-05 7.E-05  3R 8  0  3   0 0.E 00 15
*

  0.00

56 9.E 01 1.E 01 3.E 00                                  72N2 7
  (36,27)                                                10V 1
  (36, 9)                                                ( 0, 0)
                                    (36,11) 3.E-05
   3.E-05 4.E-06 1.E-06 8.E-05 3.E-05 3.E-05  3R 8  1  3   0 0.E 00 15
```

```
*

  0.00

57 6.E 01 9.E 00 3.E 00                                    72N27
   (36,10)                                                  10V 1
   (36, 9)                                                 ( 0, 0)
                              ( 1,20) 3.E-05
   2.E-05 3.E-06 1.E-06 8.E-05 1.E-05 9.E-06  3R 8  0  0  50 0.E 00 16
*

  50.00

  11.38    6.47   1  11  20  79  29  25

58 5.E 01 6.E 00 3.E 00                                    79N20
   ( 1,29)                                                  11V 1
   (29,25)                                                 (29,25)
                              (29,25) 2.E-05
   4.E-05 5.E-06 3.E-06 2.E-04 3.E-05 2.E-05  6R11  1  1   0 0.E 00 16
*

  0.00

59 4.E 01 6.E 00 2.E 00                                    79N20
   (35,29)                                                  11V 1
   ( 1, 9)                                                 ( 0, 0)
                              (35, 9) 2.E-05
   1.E-05 2.E-06 1.E-06 5.E-05 3.E-05 2.E-05  6R11  0  0  50 0.E 00 17
*

  50.00

  6.92     1.79   1   9  26  73  22  18

60 5.E 01 6.E 00 3.E 00                                    73N26
   (36,27)                                                  9V 1
   (25,18)                                                 (22,18)
                              ( 8,25) 2.E-05
   3.E-05 4.E-06 2.E-06 1.E-04 2.E-05 2.E-05  1R 6  1  1   0 0.E 00 17
*

  0.00

61 4.E 01 6.E 00 2.E 00                                    73N26
   (36,29)                                                  9V 1
   (10,24)                                                 ( 0, 0)
                              ( 4,24) 2.E-05
   2.E-05 2.E-06 1.E-06 6.E-05 3.E-05 3.E-05  1R 6  0  2   0 0.E 00 17
*

  0.00

62 5.E 01 7.E 00 2.E 00                                    73N26
   ( 1,27)                                                  9V 1
   ( 1, 9)                                                 ( 0, 0)
                              (26, 9) 2.E-05
   2.E-05 2.E-06 1.E-06 1.E-04 7.E-05 6.E-05  1R 6  0  3   0 0.E 00 17
*

  0.00

63 6.E 01 8.E 00 2.E 00                                    73N26
   ( 1,10)                                                  9V 1
   ( 1,24)                                                 ( 0, 0)
                              ( 1,24) 2.E-05
   6.E-05 4.E-06 1.E-06 8.E-05 1.E-05 7.E-06  1R 6  1  3   0 0.E 00 17
```

```
*
  0.00
.
64 3.E 01 5.E 00 2.E 00                               73N26
  (36,29)                                              9V 1
  (36, 9)                                             ( 0, 0)
                       ( 8,21) 2.E-05
  1.E-05 2.E-06 9.E-07 1.E-04 7.E-05 6.E-05  1R 6  0  3    0 0.E 00 17
*
  0.00
.
65 7.E 01 9.E 00 2.E 00                               73N26
  (36,10)                                              9V 1
  (36, 9)                                             ( 0, 0)
                       (36,10) 2.E-05
  3.E-05 3.E-06 1.E-06 9.E-05 3.E-05 3.E-05  1R 6  0  3    0 0.E 00 17
*
  0.00
.
66 5.E 01 7.E 00 2.E 00                               73N26
  ( 1,10)                                              9V 1
  ( 1,24)                                             ( 0, 0)
                       (36, 9) 2.E-05
  4.E-05 3.E-06 1.E-06 6.E-05 1.E-05 7.E-06  1R 6  1  3    0 0.E 00 17
*
  0.00
.
67 3.E 01 5.E 00 2.E 00                               73N26
  (35,29)                                              9V 1
  ( 1, 9)                                             ( 0, 0)
                       (35, 9) 2.E-05
  1.E-05 2.E-06 9.E-07 4.E-05 1.E-05 1.E-05  1R 6  0  0   50 0.E 00 18
*
 50.00

  5.10    2.88   1  11  19  80  25  17
.
68 3.E 01 5.E 00 2.E 00                               80N19
  (36,29)                                             11V 1
  (13,18)                                             (25,17)
                       (25,18) 2.E-05
  8.E-05 7.E-06 3.E-06 1.E-04 3.E-05 2.E-05  2R 5  0  1    0 0.E 00 18
*
  0.00
.
69 4.E 01 5.E 00 2.E 00                               80N19
  (36,27)                                             11V 1
  (14,17)                                             ( 0, 0)
                       (36,13) 2.E-05
  2.E-05 3.E-06 1.E-06 4.E-05 2.E-05 1.E-05  2R 5  1  2    0 0.E 00 18
*
  0.00
.
70 3.E 01 5.E 00 2.E 00                               80N19
  ( 1,27)                                             11V 1
  ( 1, 9)                                             ( 0, 0)
                       (26, 9) 2.E-05
  1.E-05 2.E-06 1.E-06 6.E-05 3.E-05 3.E-05  2R 5  0  3    0 0.E 00 18
```

```
*

   0.00
.
 71 4.E 01 5.E 00 2.E 00                                   80NI9
    ( 1,27)                                                11V 1
    ( 1,24)                                               ( 0, 0)
                          (27,10) 2.E-05
   4.E-05 2.E-06 1.E-06 1.E-04 5.E-05 4.E-05   2R 5   0   3    0 0.E 00 18
*

   0.00
.
 72 5.E 01 7.E 00 2.E 00                                   80NI9
    (36,10)                                                11V 1
    (36, 9)                                               ( 0, 0)
                          (36, 9) 2.E-05
   2.E-05 2.E-06 1.E-06 6.E-05 1.E-05 6.E-06   2R 5   1   3    0 0.E 00 18
*

   0.00
.
 73 3.E 01 4.E 00 2.E 00                                   80NI9
    (36,29)                                                11V 1
    (36, 9)                                               ( 0, 0)
                          ( 9,11) 2.E-05
   9.E-06 1.E-06 8.E-07 1.E-04 7.E-05 5.E-05   2R 5   0   3    0 0.E 00 18
*

   0.00
.
 74 6.E 01 7.E 00 2.E 00                                   80NI9
    ( 1,10)                                                11V 1
    ( 1,24)                                               ( 0, 0)
                          ( 1,24) 2.E-05
   5.E-05 3.E-06 1.E-06 9.E-05 3.E-05 3.E-05   2R 5   0   3    0 0.E 00 18
*

   0.00
.
 75 5.E 01 6.E 00 2.E 00                                   80NI9
    ( 1,10)                                                11V 1
    ( 1, 9)                                               ( 0, 0)
                          ( 1,19) 2.E-05
   2.E-05 2.E-06 9.E-07 6.E-05 1.E-05 7.E-06   2R 5   1   3    0 0.E 00 18
*

   0.00
.
 76 3.E 01 4.E 00 2.E 00                                   80NI9
    (36,29)                                                11V 1
    ( 1, 9)                                               ( 0, 0)
                          (36,20) 2.E-05
   8.E-06 1.E-06 7.E-07 3.E-05 1.E-05 8.E-06   2R 5   0   0   50 0.E 00 19
*

  50.00

   3.10     1.11    1   12   15   84   24   17
.
 77 2.E 01 4.E 00 2.E 00                                   84NI5
    ( 2,29)                                                12V 1
    (25,17)                                               (24,17)
                          (25,17) 2.E-05
   2.E-04 1.E-05 3.E-06 2.E-04 3.E-05 2.E-05   1R 3   0   1    0 0.E 00 19
```

```
*
   Ø.ØØ
.
78 3.E Ø1 5.E ØØ 2.E ØØ                           84N15
   ( 1,1Ø)                                        12V 1
   (13,18)                                       ( Ø, Ø)
                          (13,18) 2.E-Ø5
    1.E-Ø4 6.E-Ø6 2.E-Ø6 2.E-Ø4 2.E-Ø5 1.E-Ø5   IR 3   1   2     Ø Ø.E ØØ 19
*
   Ø.ØØ
.
79 3.E Ø1 4.E ØØ 2.E ØØ                           84N15
   ( 1,27)                                        12V 1
   ( 1,24)                                       ( Ø, Ø)
                          ( 1,24) 2.E-Ø5
    2.E-Ø5 2.E-Ø6 1.E-Ø6 6.E-Ø5 2.E-Ø5 2.E-Ø5   IR 3   Ø   3     Ø Ø.E ØØ 19
*
   Ø.ØØ
.
8Ø 4.E Ø1 5.E ØØ 2.E ØØ                           84N15
   (36,1Ø)                                        12V 1
   (36, 9)                                       ( Ø, Ø)
                          (27,13) 2.E-Ø5
    1.E-Ø5 2.E-Ø6 8.E-Ø7 7.E-Ø5 4.E-Ø5 3.E-Ø5   IR 3   Ø   3     Ø Ø.E ØØ 19
*
   Ø.ØØ
.
81 4.E Ø1 5.E ØØ 2.E ØØ                           84N15
   (36,1Ø)                                        12V 1
   (36, 9)                                       ( Ø, Ø)
                          ( 1,2Ø) 2.E-Ø5
    2.E-Ø5 2.E-Ø6 9.E-Ø7 5.E-Ø5 9.E-Ø6 5.E-Ø6   IR 3   1   3     Ø Ø.E ØØ 19
*
   Ø.ØØ
.
82 3.E Ø1 4.E ØØ 1.E ØØ                           84N15
   ( 1,29)                                        12V 1
   (36, 9)                                       ( Ø, Ø)
                          ( 3,24) 2.E-Ø5
    7.E-Ø6 1.E-Ø6 7.E-Ø7 1.E-Ø4 7.E-Ø5 5.E-Ø5   IR 3   Ø   3     Ø Ø.E ØØ 19
*
   Ø.ØØ
.
83 6.E Ø1 6.E ØØ 2.E ØØ                           84N15
   ( 1,1Ø)                                        12V 1
   ( 1,23)                                       ( Ø, Ø)
                          ( 1,1Ø) 2.E-Ø5
    3.E-Ø5 3.E-Ø6 1.E-Ø6 7.E-Ø5 2.E-Ø5 2.E-Ø5   IR 3   Ø   3     Ø Ø.E ØØ 19
*
   Ø.ØØ
.
84 4.E Ø1 5.E ØØ 2.E ØØ                           84N15
   (36,1Ø)                                        12V 1
   (36,1Ø)                                       ( Ø, Ø)
                          (36,12) 2.E-Ø5
    1.E-Ø5 2.E-Ø6 8.E-Ø7 4.E-Ø5 9.E-Ø6 6.E-Ø6   IR 3   1   3     Ø Ø.E ØØ 19
```

```
*
  0.00
.
85 2.E 01 4.E 00 1.E 00                        84N15
   (36,29)                                     12V 1
   ( 1, 9)                                     ( 0, 0)
                        ( 2,12) 2.E-05
   8.E-06 1.E-06 5.E-07 3.E-05 1.E-05 7.E-06   1R 3  0  0  50 0.E 00 20
*
  50.00

  1.55    .88   1  13  15  84  25  17
.
86 2.E 01 4.E 00 2.E 00                        84N15
   ( 1,10)                                     13V 1
   (25,17)                                     (25,17)
                        (13,17) 1.E-05
   2.E-04 1.E-05 3.E-06 3.E-04 4.E-05 2.E-05   0R 1  0  1   0 0.E 00 20
*
  0.00
.
87 4.E 01 4.E 00 2.E 00                        84N15
   ( 1,27)                                     13V 1
   (24,17)                                     ( 0, 0)
                        (24,17) 1.E-05
   6.E-05 4.E-06 2.E-06 8.E-05 1.E-05 1.E-05   0R 1  1  2   0 0.E 00 20
*
  0.00
.
88 3.E 01 4.E 00 1.E 00                        84N15
   (36,27)                                     13V 1
   (25,18)                                     ( 0, 0)
                        (32,12) 1.E-05
   2.E-05 2.E-06 9.E-07 4.E-05 2.E-05 2.E-05   0R 1  0  3   0 0.E 00 20
*
  0.00
.
89 3.E 01 4.E 00 1.E 00                        84N15
   (36,10)                                     13V 1
   (25,18)                                     ( 0, 0)
                        ( 8, 9) 1.E-05
   2.E-05 2.E-06 7.E-07 7.E-05 4.E-05 3.E-05   0R 1  0  3   0 0.E 00 20
*
  0.00
.
90 4.E 01 5.E 00 1.E 00                        84N15
   ( 1,10)                                     13V 1
   ( 1,24)                                     ( 0, 0)
                        ( 1,24) 1.E-05
   3.E-05 2.E-06 8.E-07 4.E-05 7.E-06 4.E-06   0R 1  1  3   0 0.E 00 20
*
  0.00
.
91 2.E 01 3.E 00 1.E 00                        84N15
   ( 1,29)                                     13V 1
   ( 1, 9)                                     ( 0, 0)
                        (11,11) 1.E-05
   7.E-06 1.E-06 6.E-07 1.E-04 5.E-05 4.E-05   0R 1  0  3   0 0.E 00 20
```

```
*

  0.00

 92 4.E 01 5.E 00 2.E 00                                 84N15
    (36,18)                                              13V 1
    (14,17)                                              ( 0, 0)
                                   (36,18) 1.E-05
    1.E-05 2.E-06 9.E-07 5.E-05 2.E-05 1.E-05  0R 1  0  3   0 0.E 00 20
*

  0.00

 93 3.E 01 4.E 00 1.E 00                                 84N15
    (36,14)                                              13V 1
    ( 1, 9)                                              ( 0, 0)
                                   (36,14) 1.E-05
    1.E-05 2.E-06 7.E-07 4.E-05 8.E-06 5.E-06  0R 1  1  3   0 0.E 00 20
*

  0.00

 94 2.E 01 3.E 00 1.E 00                                 84N15
    ( 1,29)                                              13V 1
    ( 1, 9)                                              ( 0, 0)
                                   (36,24) 1.E-05
    9.E-06 1.E-06 5.E-07 3.E-05 9.E-06 6.E-06  0R 1  0  0  50 0.E 00 21
*

 50.00

  3.98    1.11   1  13   17  82   13   17

 95 2.E 01 4.E 00 2.E 00                                 82N17
    ( 9,24)                                              13V 1
    (25,18)                                              (13,17)
                                   ( 9,25) 1.E-05
    1.E-04 1.E-05 3.E-06 5.E-04 5.E-05 2.E-05  1R 3  0  1   0 0.E 00 21
*

  0.00

 96 2.E 01 3.E 00 1.E 00                                 82N17
    (36,10)                                              13V 1
    (25,18)                                              ( 0, 0)
                                   (36,25) 1.E-05
    8.E-05 4.E-06 1.E-06 1.E-04 1.E-05 9.E-05  1R 3  1  2   0 0.E 00 21
*

  0.00

 97 2.E 01 3.E 00 1.E 00                                 82N17
    (36,27)                                              13V 1
    (25,18)                                              ( 0, 0)
                                   (25,18) 1.E-05
    4.E-05 2.E-06 7.E-07 5.E-05 2.E-05 1.E-05  1R 3  0  3   0 0.E 00 21
*

  0.00

 98 3.E 01 4.E 00 1.E 00                                 82N17
    ( 1,27)                                              13V 1
    ( 1,24)                                              ( 0, 0)
                                   (11, 9) 1.E-05
    2.E-05 2.E-06 7.E-07 7.E-05 3.E-05 3.E-05  1R 3  0  3   0 0.E 00 21
```

```
*

  0.00

99 3.E 01 4.E 00 1.E 00                                    82N17
  ( 1,10)                                                  13V 1
  ( 1,23)                                                 ( 0, 0)
                          ( 1, 9) 1.E-05
   1.E-05 2.E-06 7.E-07 3.E-05 7.E-06 4.E-06  IR 3  1  3   0 0.E 00 21
*

  0.00

100 2.E 01 3.E 00 1.E 00                                   82N17
  (36,29)                                                  13V 1
  (36,29)                                                 ( 0, 0)
                          (28,14) 1.E-05
   6.E-06 9.E-07 5.E-07 7.E-05 4.E-05 3.E-05  IR 3  0  3   0 0.E 00 21
 ITERATION LIMIT. DUMP & RELOAD TO CONTINUE
BUFFER CLEARED. SETUP RECORDED.
DATA WRITTEN ON TAPE
THIS IS THE DISC VERSION D 18JUNE73

FORTRAN STOP
$//ABSD,15,120,65140,1000
$//REW,14 25 FEB 76
$//REW,15
$//ABSL,14
$//GO
THIS IS THE DISC VERSION D 18JUNE73
RESTART
$000
ENTER ITERATION LIMIT
$200
PRINT EVERY STEP
$


ITER  RMAX   RRMS   RCCR   DMAX   DRMS  DCCC   REL  OK BA  B UB.E.C. PT
*

  0.00

101 3.E 01 4.E 00 1.E 00                                   82N17
  (36,10)                                                  13V 1
  (36,10)                                                 ( 0, 0)
                          (36,16) 1.E-05
   1.E-05 2.E-06 6.E-07 4.E-05 2.E-05 1.E-05  IR 3  0  3   0 0.E 00 21
*

  0.00

102 3.E 01 4.E 00 1.E 00                                   82N17
  ( 1,10)                                                  13V 1
  ( 1, 9)                                                 ( 0, 0)
                          ( 1, 9) 1.E-05
   1.E-05 1.E-06 6.E-07 4.E-05 6.E-06 4.E-06  IR 3  1  3.  0 0.E 00 21
```

```
*

   0.00

•
103 2.E 01 3.E 00 1.E 00                             82"17
   ( 1,29)                                           13V 1
   ( 1,24)                                          ( 0, 0)
                         (35,21) 1.E-05
   9.E-06 1.E-06 5.E-07 2.E-05 7.E-06 5.E-06  1R 3  0  0  50 0.E 00 22
*

  50.00

   6.64    5.09   1  13  13  86  12  17

•
104 2.E 01 3.E 00 2.E 00                             86N13
   (36,26)                                           13V 1
   (35,25)                                          (12,17)
                         ( 9,25) 1.E-05
   7.E-05 8.E-06 3.E-06 4.E-04 5.E-05 2.E-05  5R 6  0  1   0 0.E 00 22
*

   0.00

•
105 2.E 01 3.E 00 1.E 00                             86N13
   (36,27)                                           13V 1
   (36,25)                                          ( 0, 0)
                         (36,25) 1.E-05
   4.E-05 2.E-06 1.E-06 8.E-05 1.E-05 8.E-06  5R 6  1  2   0 0.E 00 22
*

   0.00

•
106 2.E 01 3.E 00 1.E 00                             86N13
   ( 1,27)                                           13V 1
   (35,25)                                          ( 0, 0)
                         (34, 9) 1.E-05
   1.E-05 1.E-06 6.E-07 3.E-05 1.E-05 1.E-05  5R 6  0  3   0 0.E 00 22
*

   0.00

•
107 2.E 01 3.E 00 1.E 00                             86N13
   ( 1,27)                                           13V 1
   ( 1, 9)                                          ( 0, 0)
                         ( 6,23) 1.E-05
   8.E-06 1.E-06 5.E-07 5.E-05 3.E-05 2.E-05  5R 6  0  3   0 0.E 00 22
*

   0.00

•
108 2.E 01 3.E 00 1.E 00                             86N13
   (36,27)                                           13V 1
   (36,10)                                          ( 0, 0)
                         (36,12) 1.E-05
   8.E-06 1.E-06 5.E-07 2.E-05 5.E-06 3.E-06  5R 6  1  3   0 0.E 00 22
*

   0.00

•
109 2.E 01 2.E 00 9.E-01                             86N13
   (36,29)                                           13V 1
   (36,29)                                          ( 0, 0)
                         (11,10) 1.E-05
   5.E-06 7.E-07 4.E-07 6.E-05 3.E-05 3.E-05  5R 6  0  3   0 0.E 00 22
```

```
*

  0.00

  8.41     5.97   1  12  17  82  25  17

110 3.E 01 4.E 00 1.E 00                             82N17
  ( 1,10)                                            12V 1
  ( 1, 9)                                           (25,17)
                          ( 1, 9) 1.E-05
   1.E-05 1.E-06 5.E-07 4.E-05 2.E-05 1.E-05  5R 8  0  3   0 0.E 00 22
*

  0.00

  7.96     5.97   1  12  16  83  25  17

111 2.E 01 3.E 00 1.E 00                             83N16
  ( 1,11)                                            12V 1
  ( 1,24)                                           (25,17)
                          ( 1,24) 1.E-05
   2.E-05 1.E-06 5.E-07 3.E-05 6.E-06 3.E-06  5R 7  1  3   0 0.E 00 22
*

  0.00

  7.96     5.97   1  12  16  83  25  17

112 1.E 01 2.E 00 9.E-01                             83N16
  (36,29)                                            12V 1
  (36, 9)                                           (25,17)
                          (35,24) 1.E-05
   6.E-06 7.E-07 4.E-07 2.E-05 5.E-06 4.E-06  5R 7  0  0  50 0.E 00 23
*

 50.00

  7.96     5.97   1  12  16  83  25  17

113 2.E 01 3.E 00 1.E 00                             83N16
  (32,24)                                            12V 1
  (26,17)                                           (25,17)
                          (32,25) 9.E-06
   1.E-04 9.E-06 3.E-06 4.E-04 4.E-05 2.E-05  5R 7  0  1   0 0.E 00 23
*

  0.00

  7.05     5.07   1  10  21  78  24  17

114 2.E 01 2.E 00 1.E 00                             78N21
  ( 1,27)                                            10V 1
  ( 1,25)                                           (24,17)
                          ( 1,25) 9.E-06
   5.E-05 4.E-06 1.E-06 9.E-05 1.E-05 7.E-06  5R 7  1  2   0 0.E 00 23
*
  0.00

  7.71     5.29   1  10  20  79  24  17

115 1.E 01 2.E 00 9.E-01                             79N20
  ( 1,29)                                            10V 1
  (35,25)                                           (24,17)
                          (35,25) 9.E-06
   2.E-05 1.E-06 6.E-07 5.E-05 1.E-05 1.E-05  5R 7  0  3   0 0.E 00 23
```

```
*

  0.00

  7.93     5.29   1  10  20  79  24  17

116 2.E 01 2.E 00 9.E-01                             79N20
   (36,27)                                           10V 1
   (34,24)                                          (24,17)
                             (11,11) 9.E-06
    7.E-06 1.E-06 5.E-07 4.E-05 2.E-05 2.E-05  5R 7  0  3   0 0.E 00 23
*

  0.00

  7.05     5.29   2  10  19  80  24  17

117 2.E 01 3.E 00 8.E-01                             80N19
   (36,18)                                           10V 2
   (10,24)                                          (24,17)
                             (36,14) 9.E-06
    7.E-06 1.E-06 5.E-07 2.E-05 4.E-06 2.E-06  5R 7  1  3   0 0.E 00 23
*

  0.00

  7.05     5.29   2  10  20  79  24  17

118 1.E 01 2.E 00 7.E-01                             79N20
   ( 1,29)                                           10V 2
   ( 1, 9)                                          (24,17)
                             (27, 9) 9.E-06
    4.E-06 6.E-07 3.E-07 5.E-05 3.E-05 2.E-05  5R 7  0  3   0 0.E 00 23
*

  0.00

  6.83     5.07   1  11  17  82  24  17

119 2.E 01 3.E 00 9.E-01                             82N17
   ( 1,11)                                           11V 1
   ( 1,24)                                          (24,17)
                             ( 1,24) 9.E-06
    2.E-05 1.E-06 5.E-07 4.E-05 1.E-05 8.E-06  5R 6  1  3   0 0.E 00 23
*

  0.00

  6.83     5.29   1  11  17  82  24  17

120 2.E 01 3.E 00 8.E-01                             82N17
   (36,10)                                           11V 1
   (36, 9)                                          (24,17)
                             (36, 9) 9.E-06
    8.E-06 9.E-07 4.E-07 2.E-05 4.E-06 3.E-06  5R 6  0  0  50 0.E 00 24
*

 50.00

  6.83     5.51   1  11  17  82  24  17

121 2.E 01 2.E 00 1.E 00                             82N17
   (24,18)                                           11V 1
   (25,17)                                          (24,17)
                             (28,25) 8.E-06
    2.E-04 1.E-05 2.E-06 3.E-04 3.E-05 1.E-05  5R 6  0  1   0 0.E 00 24
```

```
*

  0.00

  7.05     2.64    1    9   24   75   25   17

122 1.E 01 2.E 00 8.E-01                          75N24
   ( 1,27)                                         9V 1
   (14,16)                                        (25,17)
                        (14,16) 8.E-06
   2.E-05 2.E-06 8.E-07 3.E-05 8.E-06 6.E-06  2R 7   1   2    0 0.E 00 24
*

  0.00

  7.49     2.86    1    9   25   74   25   17

123 1.E 01 2.E 00 8.E-01                          74N25
   ( 1,27)                                         9V 1
   (13,18)                                        (25,17)
                        (13,18) 8.E-06
   2.E-05 1.E-06 4.E-07 2.E-05 6.E-06 4.E-06  2R 7   0   0   50 0.E 00 25
*

 50.00

  7.71     2.86    2    9   26   73   25   17

124 1.E 01 2.E 00 1.E 00                          73N26
   (36,27)                                         9V 2
   (25,17)                                        (25,17)
                        (25,17) 7.E-06
   2.E-04 1.E-05 2.E-06 3.E-04 3.E-05 1.E-05  2R 7   0   1    0 0.E 00 25
*

  0.00

  9.47     3.08    1    7   31   68   13   17

125 2.E 01 2.E 00 9.E-01                          68N31
   (25,19)                                         7V 1
   (14,17)                                        (13,17)
                        (24,18) 7.E-06
   5.E-05 3.E-06 1.E-06 9.E-05 2.E-05 2.E-05  3R 9   0   2    0 0.E 00 25
*

  0.00

  8.15     2.64    1    7   29   70   13   17

126 2.E 01 2.E 00 8.E-01                          70N29
   ( 1,27)                                         7V 1
   (13,18)                                        (13,17)
                        (24,16) 7.E-06
   3.E-05 2.E-06 8.E-07 4.E-05 5.E-06 3.E-06  2R 8   1   3    0 0.E 00 25
*

  0.00

  7.93     2.86    1    7   28   71   24   17

127 1.E 01 1.E 00 6.E-01                          71N28
   ( 1,29)                                         7V 1
   ( 1,29)                                        (24,17)
                        (25,13) 7.E-06
   4.E-06 6.E-07 3.E-07 4.E-05 2.E-05 1.E-05  2R 7   0   3    0 0.E 00 25
```

```
*

  0.00

  7.93     3.08   1   8  27  72  24  17

128 2.E 01 2.E 00 7.E-01                              72N27
  (36,27)                                              8V 1
  (36, 9)                                            (24,17)
                             (36,10) 7.E-06
  7.E-06 9.E-07 4.E-07 2.E-05 7.E-06 6.E-06  3R 7  1  3    0 0.E 00 25
*

  0.00

  8.15     3.08   2   8  28  71  24  17

129 1.E 01 2.E 00 6.E-01                              71N28
  (36,28)                                              8V 2
  (36, 9)                                            (24,17)
                             ( 1,20) 7.E-06
  5.E-06 7.E-07 3.E-07 2.E-05 3.E-06 2.E-06  3R 8  0  0   50 0.E 00 25
*

 50.00

  7.93     3.08   2   8  28  71  24  17

130 1.E 01 2.E 00 8.E-01                              71N28
  ( 1,29)                                              8V 2
  (25,17)                                            (24,17)
                             ( 9,25) 7.E-06
  7.E-05 7.E-06 2.E-06 2.E-04 2.E-05 7.E-06  3R 7  0  1    0 0.E 00 25
*

  0.00

  8.59     3.96   2   6  34  65  12  17

131 1.E 01 1.E 00 6.E-01                              65N34
  ( 1,27)                                              6V 2
  (13,18)                                            (12,17)
                             (25,18) 7.E-06
  2.E-05 1.E-06 5.E-07 3.E-05 6.E-06 5.E-06  3R 8  1  2    0 0.E 00 25
*

  0.00

  8.81     4.63   2   6  33  66  25  17

132 1.E 01 2.E 00 6.E-01                              66N33
  (36,27)                                              6V 2
  (23,17)                                            (25,17)
                             (34,29) 7.E-06
  6.E-06 6.E-07 3.E-07 1.E-05 4.E-06 3.E-06  4R 8  0  0   50 0.E 00 25
*

 50.00

  9.03     4.85   2   6  33  66  25  17

133 1.E 01 2.E 00 7.E-01                              66N33
  (36,29)                                              6V 2
  (22,24)                                            (25,17)
                             ( 7,25) 6.E-06
  3.E-05 3.E-06 1.E-06 1.E-04 2.E-05 8.E-06  4R 9  0  1    0 0.E 00 25
```

```
*
 0.00
 10.79    .88   3   6  75  24  12  17
•
134 1.E 01 2.E 00 6.E-01                             24N75
 ( 1,27)                                              6V 3
 ( 1,25)                                            (12,17)
                              ( 1,25) 6.E-06
 2.E-05 1.E-06 5.E-07 4.E-05 9.E-06 7.E-06  0R10  0  2    0 0.E 00 25
*
 0.00
 10.79   1.98   3   6  70  29  25  17
•
135 2.E 01 2.E 00 6.E-01                             29N70
 ( 1,27)                                              6V 3
 ( 1,25)                                            (25,17)
                              (35,25) 6.E-06
 8.E-06 8.E-07 4.E-07 2.E-05 3.E-06 2.E-06  1R10  1  3    0 0.E 00 25
*
 0.00
 10.57   2.20   3   6  70  29  12  17
•
136 1.E 01 1.E 00 4.E-01                             29N70
 (36,29)                                              6V 3
 ( 2,25)                                            (12,17)
                              (28,10) 6.E-06
 3.E-06 3.E-07 2.E-07 2.E-05 1.E-05 9.E-06  2R10  0  3    0 0.E 00 25
*
 0.00
 10.13   2.20   3   6  59  40  12  17
•
137 2.E 01 2.E 00 6.E-01                             40N59
 (36,27)                                              6V 3
 (36,26)                                            (12,17)
                              (36,10) 6.E-06
 5.E-06 6.E-07 2.E-07 1.E-05 6.E-06 5.E-06  2R10  1  3    0 0.E 00 25
*
 0.00
 10.13   2.20   2   6  54  45  12  17
•
138 1.E 01 2.E 00 5.E-01                             45N54
 ( 1,27)                                              6V 2
 ( 1,24)                                            (12,17)
                              (36, 9) 6.E-06
 6.E-06 5.E-07 2.E-07 9.E-06 2.E-06 1.E-06  2R10  0  0   50 0.E 00 25
*
 50.00
 10.13   2.20   2   6  54  45  12  17
•
139 9.E 00 1.E 00 6.E-01                             45N54
 (35,29)                                              6V 2
 (12,17)                                            (12,17)
                              (13,18) 6.E-06
 5.E-05 4.E-06 1.E-06 7.E-05 1.E-05 5.E-06  2R10  1  1    0 0.E 00 25
```

```
*
  0.00

  7.49      .66   2   7  90   9  13  17

i40 9.E 00 1.E 00 5.E-01                               9N90
   (36,29)                                             7V 2
   (25,16)                                           (13,17)
                               (23,15) 6.E-06
    7.E-06 8.E-07 4.E-07 1.E-05 4.E-06 3.E-06  0R 7   0   0   50 0.E 00 25
*
 50.00

  8.37      .66   2   7  90   9  13  17

i41 1.E 01 1.E 00 5.E-01                               9N90
   (36,28)                                             7V 2
   (13,18)                                           (13,17)
                               (13,17) 6.E-06
    7.E-05 5.E-06 1.E-06 1.E-04 8.E-06 4.E-06  0R 8   1   1    0 0.E 00 25
*
  0.00

  7.05     1.32   2   7  94   5  12  16

i42 9.E 00 1.E 00 4.E-01                               5N94
   ( 1,27)                                             7V 2
   (13,18)                                           (12,16)
                               (13,18) 6.E-06
    5.E-05 2.E-06 4.E-07 7.E-05 6.E-06 4.E-06  1R 7   0   0   50 0.E 00 25
*
 50.00

  7.93     1.32   2   9  93   6  12  17

i43 1.E 01 1.E 00 5.E-01                               6N93
   ( 1,27)                                             9V 2
   (13,17)                                           (12,17)
                               (25,17) 5.E-06
    8.E-05 5.E-06 1.E-06 1.E-04 1.E-05 8.E-06  1R 7   0   1    0 0.E 00 25
*
  0.00

 11.45      .44   2   6  95   4  25  17

i44 1.E 01 1.E 00 5.E-01                               4N95
   (36,27)                                             6V 2
   (25,18)                                           (25,17)
                               (25,18) 5.E-06
    6.E-05 3.E-06 7.E-07 8.E-05 5.E-06 2.E-06  0R11   1   2    0 0.E 00 25
*
  0.00

 11.89     1.98   2   7  95   4  24  17

i45 7.E 00 8.E-01 3.E-01                               4N95
   (36,29)                                             7V 2
   (14,17)                                           (24,17)
                               (14,16) 5.E-06
    1.E-05 6.E-07 2.E-07 3.E-05 9.E-06 8.E-06  1R11   0   3    0 0.E 00 25
```

```
*

  0.00

 11.01     1.98    2    7   94    5   24   17

146 1.E 01 1.E 00 4.E-01                              5N94
   ( 1,27)                                             7V 2
   ( 1,24)                                            (24,17)
                              ( 1,24) 5.E-06
    7.E-06 6.E-07 2.E-07 1.E-05 4.E-06 3.E-06  1R11   1   3     0 0.E 00 25
*

  0.00

 10.79     2.20    2    7   94    5   24   17

147 9.E 00 1.E 00 4.E-01                              5N94
   ( 1,27)                                             7V 2
   ( 1,26)                                            (24,17)
                              ( 1,19) 5.E-06
    3.E-06 4.E-07 2.E-07 7.E-06 2.E-06 1.E-06  2R10   0   0    50 0.E 00 25
*

 50.00

 10.79     2.20    2    7   94    5   24   17

148 7.E 00 8.E-01 4.E-01                              5N94
   (36,29)                                             7V 2
   (13,18)                                            (24,17)
                              (13,17) 5.E-06
    3.E-05 3.E-06 9.E-07 6.E-05 6.E-06 3.E-06  2R10   1   1     0 0.E 00 25
*

  0.00

 11.89      .88    1    6   98    1   12   17

149 6.E 00 7.E-01 3.E-01                              1N98
   ( 2,29)                                             6V 1
   (14,17)                                            (12,17)
                              (24,14) 5.E-06


SOLUTION


ITER  RMAX   RRMS   RCCR   DMAX   DRMS  DCCC    REL  OK BA  B UB.E.C. PT
 149 6.E 00 7.E-01 3.E-01                       1N98
    5.E-06 5.E-07 2.E-07 7.E-06 2.E-06 2.E-06  0R11   0   0    50 0.E 00 25
BUFFER CLEARED. SETUP RECORDED.
DATA WRITTEN ON TAPE
THIS IS THE DISC VERSION D 18JUNE73

FORTRAN STOP
$//ABSD,15,120,65140,1000
```

OTFN

The following programs are run at time during the execution of SOLVE program. The output printout supplies additional field condition indicators regarding the suitability of the solution algorithm.

Program OTFN maps field conditions by printout on line printer or teletypewriter printer. This analysis was performed only at location 1, and problems associated with rotor motion and location 2 were not considered. In addition, eddy currents and eddy-current losses were not considered so maps related to these conditions are not shown. The maps are shown in order as requested from the main program.

The main program OTFN recalculates residual by call of Subroutine RES. The R matrix is used as scratch matrix as residual values of each node must be recalculated before printout. The value of R matrix is multiplied by Scale and changed to integer values for printing. The scale of 1000 shown in heading is multiplier so values in residual map must be divided by 1000 for true values.

The clustering groups of negative residuals in the left-side region of air and positive residuals in the right-side region of air instead of intermixed positive and negative values are phenomena which remain unexplained. This clustering of negative and positive residuals in which maximum residual values occur either in the first or last columns is frequently observed in the iteration printout of the program SOLVE.

Print B provides an option to print a magnetic induction, or B, map. With this printout is a double conversion from metric to English units and from real to integer values. During this later conversion, a system error message is encountered when the value of B exceeds 32,767, the maximum integer value for single-precision, 16-bit integer variable. Although the error is not fatal, it does, in addition, provide a highly saturated flux condition especially for no-load conditions simulated on the alternator.

The print field angle prints a grid map of field angles in degrees. The arc tangent function of the X-component of the magnetic induction provides the angle subtended from the vertical. A negative angle means the direction of the X-component is to the left of vertical, and a positive angle means the X-component of B lies to the right. The angle along iron-air interfaces indicates flux at these interfaces is at right angles which is the desired condition. The field angle at vertical boundaries from iron is nearly 90 degrees which is again the proper field condition for solution of the present alternator configuration.

The relative permeability data is stored in DMAT matrix as the ratio of reluctivity

of space, 0.7957747E+06, to relative reluctivity of the material. The relative permeability is obtained by taking the reciprocal of the DMAT variable, multiplying by the reluctivity of air, and converting from a real to an integer variable. The relative permeability of the stator steel is in the 5000 range for unsaturated portions of the path. The value of permeability reduces for saturated grid spaces. Similarly, the relative permeability of the rotor iron is in the 300 range. The relative permeability of air grid spaces has value of unity.

The vector potential map in units of webers/meter consists of a vector in Z-plane. The positive value of vector potential can be considered a vector out of the page, or plane, of alternator configuration. On the opposite boundary, the negative value can be considered a vector into the page.

A similar group of printouts may be selected at rotor in location 2. However, this option was not exercised for this example, and certain variables requiring setup for material motion were never set. These printouts serve mainly to indicate values which can be associated with graphic representations shown in the next program.

PRINT R
$

RESIDUALS IN AMPS X 1000 LOCATION = 1 PROBLEM LJ51

J	1	2	3	4	5	6	7	8	9	10
29	-5274	-4532	-4453	-4221	-3948	-3648	-3331	-3005	-2674	-2344
28	-6101	-211	-295	-321	-333	-334	-326	-318	-304	-283
27	-6853	-201	-303	-323	-320	-301	-290	-268	-242	-225
26	-4638	-312	-256	-283	-262	-256	-227	-187	-169	-148
25	-77	34	-92	-12	0	-16	-6	0	-5	8
24	-43	-43	-295	-1	-23	-128	0	-10	-53	
23	0	-36	-280	0	-49	-169	0	-26	-114	
22	-1	-51	-215	0	-77	-187	0	-52	-123	
21	-1	-82	-163	0	-71	-228	0	-87	-130	
20	-368	-232	-275	-180	-227	-256	-164	-165	-142	-24
19	-3151	-884	-505	-380	-512	-393	-343	-441	-223	-85
18	-3119	-475	-388	-330	-346	-306	-301	-254	-2	-5
17	-3215	-396	-428	-389	-351	-307	-248	-182	-57	-33
16	-3302	-380	-436	-410	-375	-344	-310	-170	-85	-16
15	-3354	-380	-432	-404	-361	-314	-267	-200	-158	-132
14	-3381	-382	-427	-395	-347	-293	-242	-192	-168	-169
13	-3396	-376	-415	-381	-334	-281	-229	-183	-159	-162
12	-3415	-361	-393	-360	-317	-269	-219	-173	-145	-142
11	-3477	-350	-364	-333	-295	-253	-206	-159	-122	-105
10	-3751	-388	-351	-314	-278	-241	-199	-149	-99	-59
9	-2432	-328	-291	-252	-218	-190	-164	-134	-91	-41
8	-10	-1	-1	0	0	0	0	0	-1	
7	-9	-1								
6	-13	-1	-1	0	0	0	0	0	0	-1
5	-10	-1								
4	-637	-21	-53	-65	-70	-70	-69	-66	-62	-58
3	-2368	-129	-157	-152	-145	-137	-128	-119	-108	-98
2	-2176	-186	-145	-125	-111	-101	-91	-82	-73	-64
1	-1860	-1520	-1462	-1407	-1350	-1289	-1223	-1152	-1074	-989

RESIDUALS IN AMPS X 1000 LOCATION = 1 PROBLEM LJ51

J	11	12	13	14	15	16	17	18	19	20
29	-2018	-1699	-1386	-1084	-791	-506	-228	43	311	575
28	-262	-237	-208	-176	-144	-111	-79	-49	-18	10
27	-204	-179	-153	-125	-96	-67	-38	-10	17	45
26	-126	-105	-83	-63	-37	-13	8	31	55	79
25	0	1								
24	-3	6	0	1	175	2	-16	-7	0	-1
23	2	-34	1	36	224	-15	-20	-24	-1	-13
22	3	-47	2	0	202	-9	3	-39	-1	-13
21	-9	6	0	-273	73	-5	168	21	-3	-9
20	-7	19	-368	-45	-40	267	8	-30	-27	-2
19	-139	61	-115	84	-57	3	-65	-28	-7	-1
18	-224	-116	193	-105	8	7	-40	2	-1	-21
17	285	60	-28	12	-4	0	0	2	1	
16	53	-12	4	5	-1	-1	1	0	0	2
15	-153	-6	8	2	1					
14	-153	0	2	2	1					
13	-142	2	1							
12	-127	3								
11	-93	3	-1	0	1					
10	-41	3	-1							
9	2	1	0	0	0	0	0	0	0	-1
8	0	1	0	0	0	0	0	0	0	-1
7	0									
6	0									
5	-1									
4	-53	-48	-43	-37	-32	-26	-20	-14	-8	-2
3	-87	-76	-66	-56	-46	-34	-22	-10	2	14
2	-56	-48	-41	-33	-25	-16	-7	1	11	21
1	-899	-804	-706	-606	-505	-402	-299	-194	-88	19

RESIDUALS IN AMPS X 1000   LOCATION = 1   PROBLEM 1J51

J	21	22	23	24	25	26	27	28	29	30
29	835	1093	1349	1602	1853	2100	2344	2582	2812	3029
28	40	67	96	123	151	180	211	242	274	307
27	72	99	124	150	174	199	223	244	266	286
26	102	125	147	169	191	212	228	247	261	261
25	0	0	0	1	4	0	7	6	1	13
24	-59	1	-3	105	0	9	-74	-4	5	163
23	-23	2	-69	109	8	-10	-102	0	29	109
22	78	-62	-97	36	1	17	-96	0	20	75
21	43	-52	146	4	0	225	-28	0	42	25
20	-71	227	-7	5	303	44	7	43	12	81
19	50	105	193	44	163	14	80	101	209	291
18	-14	-9	-216	96	-121	-55	22	32	70	136
17	4	5	11	-48	-70	31	15	135	142	244
16	3	6	0	-27	8	8	51	234	247	234
15	1	1	1	2	-1	-13	98	213	239	250
14	-1	0	1	0	-1	-2	95	204	228	252
13	-1	-2	-2	2	1	-2	102	201	222	249
12	-1	-2	-3	2	3	-2	107	193	215	243
11	0	-2	-4	2	3	-1	112	180	209	240
10	-1	-2	-3	2	4	0	131	179	222	258
9	-1	-2	-2	2	6	5	98	159	202	241
8	-2	-1	-1	1	4	5	1	0	2	1
7	0	0	0	0	1	2	2	2	1	1
6	0	0	1	0	0	1	1	1	1	1
5	0									
4	3	10	16	23	29	36	42	48	53	59
3	27	40	53	65	77	86	94	101	107	111
2	31	42	51	60	67	73	77	80	81	80
1	131	245	364	485	609	733	856	972	1079	1171

RESIDUALS IN AMPS X 1000 LOCATION = 1 PROBLEM LJ51

J	31	32	33	34	35	36
29	3223	3378	3463	3424	5094	5232
28	339	361	361	320	3922	1084
27	292	295	285	248	3784	883
26	253	233	201	149	1654	-13
25	8	1	15	12	-88	26
24	-3	11	261	-5	-30	881
23	0	60	202	0	125	969
22	0	70	129	0	151	976
21	0	134	44	0	179	479
20	155	190	163	223	416	2131
19	472	470	422	617	891	1505
18	329	277	329	489	1104	1565
17	282	307	349	409	1237	1587
16	280	321	358	369	1276	1595
15	287	328	358	354	1285	1593
14	288	327	354	346	1280	1579
13	284	321	346	339	1266	1550
12	276	309	330	326	1239	1510
11	270	294	304	294	1182	1544
10	288	301	286	243	1107	1334
9	274	292	281	234	677	4
8	1	1	1	1	3	3
7	1	1	1	0	2	4
6	1	1	1	0	4	1
5	1	1	1	0	5	1
4	65	70	72	71	809	383
3	113	111	106	95	1352	364
2	76	70	61	48	1233	303
1	1240	1277	1269	1206	1815	1328

PRINT B
$

INDUCTION IN GAUSS LOCATION = 1 PROBLEM LJ51

J	1	2	3	4	5	6	7	8	9	10
29	143	202	286	377	470	560	646	724	794	853
28	71	159	258	358	455	549	638	718	790	850
27	317	348	404	474	554	638	718	794	863	917
26	583	607	646	684	757	844	902	974	1065	1107
25	20140	20381	20176	20130	20393	20225	20040	20228	20031	19068
24	19980	20788	20071	19884	20801	20194	19509	20543	20180	17857
23	6806	2256	7089	6554	2351	7729	5482	2120	10975	8477
22	2932	2257	3096	2926	2350	3959	2911	2116	10552	10254
21	2403	2258	2471	2509	2352	3226	3167	2126	10981	11011
20	2552	2259	2594	2775	2358	3029	4015	2384	10947	11229
19	769	1056	702	1038	1180	852	2787	2605	10725	10773
18	768	885	808	982	1187	1390	2509	3171	9716	13319
17	790	845	889	1028	1301	1813	3192	6267	11804	21825
16	779	820	890	1018	1228	1525	1884	1961	1188	2731
15	732	769	842	958	1126	1341	1582	1559	1316	1698
14	654	692	765	875	1023	1205	1408	1376	1187	1245
13	553	594	672	783	926	1096	1286	1231	998	930
12	435	484	573	693	839	1007	1193	1111	811	661
11	307	373	480	614	768	938	1123	1016	645	407
10	176	275	408	557	719	892	1075	947	514	146
9	81	227	377	534	700	873	1053	911	440	170
8	16292	16311	16349	16408	16492	16608	16792	17014	17200	17764
7	16310	16330	16369	16430	16515	16633	16800	16979	17159	17492
6	16326	16347	16387	16448	16534	16649	16795	16948	17100	17241
5	16349	16370	16411	16474	16559	16664	16781	16900	16985	16911
4	16364	16385	16427	16489	16570	16664	16758	16826	16819	16652
3	50	51	54	58	64	71	79	88	97	106
2	28	30	34	40	47	55	64	72	81	89
1	6	12	21	29	38	47	57	65	74	82

INDUCTION IN GAUSS LOCATION = 1 PROBLEM LJ51

J	11	12	13	14	15	16	17	18	19	20
29	900	937	965	985	998	1007	1013	1015	1015	1013
28	899	936	964	985	998	1007	1013	1015	1015	1013
27	956	984	1002	1013	1020	1024	1026	1026	1026	1026
26	1104	1096	1089	1076	1061	1051	1046	1043	1043	1046
25	17831	17091	16091	14351	12052	10285	9146	4506	4504	9143
24	17085	17739	15312	8774	14075	13742	7443	13677	13676	7443
23	504	17352	18415	317	19201	19311	379	19379	19376	378
22	655	18226	18012	368	19238	19323	408	19394	19391	408
21	914	18221	18290	644	19226	19284	637	19333	19331	637
20	1927	17871	17893	2070	13663	18702	2072	18692	18690	2072
19	2949	17541	17389	3326	18142	18135	3326	18096	18096	3326
18	4161	17852	19144	2630	18709	18775	2358	18620	18620	2358
17	20933	20236	20280	11049	17378	17737	8318	17007	17007	8319
16	19337	19095	17065	16916	16348	15351	15371	15209	15210	15371
15	17604	16921	17094	16676	16364	16293	16150	16114	16115	16150
14	16935	17100	16837	16780	16701	16610	16578	16553	16553	16577
13	17041	16963	16954	16896	16847	16818	16794	16782	16782	16793
12	17054	17054	17017	16987	16958	16935	16922	16912	16912	16921
11	17134	17091	17082	17048	17022	17007	16983	16967	16966	16982
10	17225	17190	17159	17099	17045	16997	16946	16918	16918	16945
9	17752	17481	17253	17073	16929	16814	16739	16703	16702	16738
8	18946	17549	17075	16746	16506	16348	16260	16221	16220	16258
7	17554	17284	16588	16119	15820	15559	15383	15284	15284	15381
6	17080	16567	16051	15473	15035	14483	14015	13706	13705	14014
5	16533	15904	15154	14150	12913	11546	10356	9684	9684	10354
4	16206	15325	13890	11938	9665	7306	5106	3565	3564	5103
3	114	119	121	123	124	125	126	127	127	126
2	96	102	107	111	114	116	117	118	118	117
1	89	96	101	106	109	112	113	114	114	113

INDUCTION IN GAUSS LOCATION = 1 PROBLEM LJ51

J	21	22	23	24	25	26	27	28	29	30
29	1008	999	985	966	938	901	854	795	725	647
28	1008	999	985	965	937	900	851	791	719	639
27	1024	1020	1014	1003	984	957	918	863	795	719
26	1051	1061	1076	1089	1097	1104	1107	1065	975	903
25	10280	12050	14352	16091	17092	17833	19073	20038	20234	20045
24	13721	14099	8775	15316	17744	17088	17860	20177	20541	19505
23	19273	19251	317	18423	17361	504	8478	10972	2119	5482
22	19289	19282	368	18018	18236	654	10254	10552	2115	2910
21	19250	19269	644	18297	18230	914	11011	10982	2125	3166
20	18685	18687	2072	17900	17878	1928	11229	10948	2383	4013
19	18134	18149	3327	17397	17549	2950	10773	10725	2604	2786
18	18775	18715	2631	19155	17858	4164	13316	9716	3170	2508
17	17737	17382	11056	20292	20233	20924	21817	11800	6264	3191
16	15351	16353	16924	17062	19093	19334	2733	1188	1959	1883
15	16293	16366	16677	17090	16928	17604	1699	1317	1559	1581
14	16609	16701	16779	16837	17105	16937	1245	1187	1375	1408
13	16817	16845	16894	16959	16964	17042	930	998	1231	1285
12	16933	16954	16985	17024	17054	17052	661	811	1110	1192
11	17004	17018	17045	17091	17092	17130	406	645	1015	1122
10	16994	17040	17097	17167	17191	17220	146	514	947	1074
9	16811	16924	17069	17260	17483	17749	171	440	911	1052
8	16345	16502	16742	17080	17552	18943	17758	17194	17008	16787
7	15556	15816	16116	16590	17288	17556	17493	17159	16980	16800
6	14481	15032	15470	16051	16569	17084	17246	17104	16950	16796
5	11544	12911	14148	15152	15901	16530	16908	16982	16898	16780
4	7303	9661	11934	13886	15322	16204	16649	16816	16824	16756
3	125	124	123	121	119	114	106	97	88	79
2	116	114	111	107	102	96	89	81	72	64
1	112	109	106	101	96	89	82	74	65	57

INDUCTION IN GAUSS LOCATION = 1 PROBLEM LJ51

J	31	32	33	34	35	36
29	561	471	378	286	205	145
28	550	456	359	259	163	75
27	639	555	475	405	351	318
26	845	757	685	646	608	583
25	20233	20401	20135	20179	20382	20140
24	20187	20791	19878	20067	20786	19977
23	7726	2351	6551	7086	2252	6796
22	3957	2351	2925	3094	2256	2927
21	3225	2353	2510	2472	2259	2403
20	3029	2358	2775	2596	2261	2555
19	852	1180	1038	703	1060	778
18	1390	1187	983	808	887	772
17	1813	1301	1028	890	846	790
16	1525	1228	1018	891	820	779
15	1340	1125	958	842	769	732
14	1204	1022	875	765	691	654
13	1095	925	783	671	593	553
12	1006	838	692	572	483	434
11	937	767	613	479	371	305
10	891	718	556	407	273	174
9	872	698	533	376	223	76
8	16605	16490	16406	16348	16310	16292
7	16633	16514	16429	16369	16330	16310
6	16649	16534	16448	16386	16346	16326
5	16662	16557	16473	16411	16369	16349
4	16662	16568	16488	16426	16385	16364
3	71	64	58	54	51	50
2	55	47	40	34	30	28
1	48	39	30	21	13	6

```
PRINT FIELD ANGLE
$
```

FIELD ANGLE IN DEGREES LOCATION = 1 PROBLEM LJ51

J	1	2	3	4	5	6	7	8	9	1Ø
29	71	42	28	2Ø	15	12	9	7	6	4
28	-49	-2Ø	-12	-8	-6	-5	-4	-3	-2	-1
27	-81	-63	-49	-39	-32	-25	-21	-17	-13	-1Ø
26	-86	-75	-64	-57	-48	-4Ø	-34	-28	-21	-15
25	-88	-89	-87	-89	-88	-86	-88	-87	-84	-8Ø
24	-77	-89	-76	-79	-89	-75	-82	-88	-69	-7Ø
23	-5Ø	-89	-47	-53	-87	-4Ø	-61	-85	-14	-12
22	-74	-89	-67	-82	-89	-46	-72	-88	-1Ø	-6
21	-88	-89	-8Ø	-83	-89	-53	-53	-84	-9	-6
2Ø	-82	-89	-87	-76	-86	-7Ø	-52	-62	-8	-1Ø
19	-53	-88	-61	-44	-75	-52	-27	-38	-2	-3
18	-75	-88	-81	-66	-76	-66	-46	-45	-27	-21
17	-87	-89	-87	-86	-87	-86	-85	-88	-72	-67
16	-88	-85	-83	-82	-8Ø	-75	-64	-42	-79	-58
15	-86	-82	-77	-73	-69	-63	-54	-52	-81	-79
14	-85	-77	-7Ø	-64	-59	-53	-47	-5Ø	-71	-89
13	-83	-72	-63	-55	-49	-44	-39	-43	-62	-84
12	-8Ø	-65	-54	-45	-39	-34	-3Ø	-34	-52	-8Ø
11	-75	-54	-41	-33	-28	-24	-2Ø	-23	-38	-75
1Ø	-63	-35	-24	-18	-15	-12	-1Ø	-11	-19	-62
9	-9	-3	-2	-2	-1	-1	Ø	Ø	4	Ø
8	89	89	88	88	87	87	86	87	88	8
7	89	89	88	88	88	87	87	88	89	85
6	89	89	89	88	88	88	88	88	-89	85
5	89	89	89	89	88	88	89	89	89	86
4	89	89	89	89	89	89	89	89	89	88
3	87	78	69	61	54	48	43	37	32	26
2	85	68	54	44	36	3Ø	26	22	18	15
1	62	25	15	1Ø	8	6	5	4	3	3

FIELD ANGLE IN DEGREES   LOCATION = 1   PROBLEM LJ51

.J	11	12	13	14	15	16	17	18	19	20
29	3	2	2	1						
28	-1	-1								
27	-7	-5	-4	-2	-1	-1				
26	-11	-7	-5	-3	-1	-1				
25	-83	-83	-78	-73	-73	-63	-34	-17	16	34
24	-84	-56	-37	-64	-27	-6	-15	-10	10	15
23	-66	1	2	-4	0	0	-2	0	0	2
22	-75	-2	-1	-26	0	0	-5	0	0	6
21	-66	-1	-1	-28	0	0	-5	0	0	5
20	-32	-1	-4	-11	0	-2	-2	1	-1	2
19	-20	-1	0	-4						
18	-47	-10	-4	-13	-2	0	-1	-1	1	1
17	-57	-23	-30	-36	-4	-19	-14	7	-7	4
16	-12	-20	-23	-17	-16	-12	-6	-2	2	6
15	-8	-9	-8	-8	-6	-4	-3	-1	1	3
14	-3	-4	-4	-3	-3	-2	-1	0	0	1
13	-3	-2	-2	-2	-1	-1				
12	-2	-1	-1	-1	-1					
11	-1									
10	0									
9	2	4	4	4	3	2	1	0	0	-1
8	45	23	16	11	8	5	3	1	-1	-3
7	66	45	30	22	16	11	6	2	-2	-6
6	73	59	44	34	26	19	11	4	-4	-11
5	80	71	60	51	42	32	21	7	-7	-21
4	86	83	79	75	69	62	49	21	-21	-49
3	21	16	13	9	7	5	2	0	0	-2
2	12	10	8	6	4	3	1	0	0	-1
1	2	2	1	1						

FIELD ANGLE IN DEGREES   LOCATION = 1   PROBLEM LJ51

J	21	22	23	24	25	26	27	28	29	30
29	0	-1	-1	-2	-2	-3	-4	-6	-7	-9
28	0	0	0	0	1	1	1	2	3	4
27	1	1	2	4	5	7	10	13	17	21
26	1	1	3	5	7	11	15	21	28	3
25	63	73	73	78	83	83	80	84	87	88
24	6	27	64	37	56	84	70	69	88	82
23	0	0	4	-2	-1	65	12	14	85	61
22	0	0	26	1	2	75	6	10	88	2
21	0	0	28	1	1	66	6	9	84	54
20	2	0	11	4	1	32	10	8	62	5
19	0	0	4	0	1	20	3	2	38	27
18	0	2	13	4	10	48	21	27	45	46
17	19	4	36	30	23	57	67	72	88	85
16	12	16	17	23	20	12	58	79	42	64
15	5	6	8	8	9	8	79	81	52	54
14	2	3	3	4	4	3	89	71	50	7
13	1	1	2	2	2	3	84	62	43	39
12	0	1	1	1	1	2	80	52	34	8
11	0	0	0	0	0	1	75	38	23	20
10	0	0	0	0	0	0	62	19	11	0
9	-2	-3	-4	-4	-4	-2	-70	-4		
8	-5	-8	-11	-16	-23	-45	-87	-88	-87	-86
7	-11	-16	-22	-30	-45	-66	-85	89	-88	-87
6	-19	-26	-34	-44	-59	-73	-85	-89	-88	-88
5	-32	-42	-51	-60	-71	-80	-86	-89	-89	-88
4	-62	-69	-75	-79	-83	-86	-88	-89	-89	-89
3	-5	-7	-9	-13	-16	-21	-26	-32	-37	-43
2	-3	-4	-6	-8	-10	-12	-15	-18	-22	-8
1	0	0	-1	-1	-2	-2	-3	-3	-4	-5

FIELD ANGLE IN DEGREES LOCATION = 1 PROBLEM LJ51

J	31	32	33	34	35	36
29	-12	-15	-20	-27	-41	-68
28	5	6	8	11	19	46
27	25	31	39	49	63	80
26	40	48	57	63	74	86
25	86	88	89	87	89	88
24	75	89	79	76	89	77
23	40	87	53	47	89	50
22	46	89	82	67	89	74
21	53	89	83	80	89	88
20	70	86	76	87	89	82
19	52	75	44	61	88	52
18	66	76	66	81	88	74
17	86	87	86	87	89	87
16	75	80	82	83	86	89
15	63	69	73	77	82	87
14	53	59	65	70	78	85
13	44	49	56	63	72	84
12	34	39	45	54	66	81
11	24	28	33	41	55	76
10	12	15	18	24	36	65
9	1	1	2	2	4	10
8	-87	-87	-88	-88	-89	-89
7	-87	-88	-88	-88	-89	-89
6	-88	-88	-88	-89	-89	-89
5	-88	-88	-89	-89	-89	-89
4	-89	-89	-89	-89	-89	-89
3	-48	-54	-61	-69	-76	-85
2	-30	-36	-44	-54	-65	-82
1	-6	-8	-10	-15	-23	-52

PRINT PERMEABILITY
$
RELATIVE PERMEABILITY LOCATION = 1 PROBLEM LJ51

J	1	2	3	4	5	6	7	8	9	10
29	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1
25	30	24	29	30	23	27	34	27	34	62
24	-37	-18	-34	-38	17	-29	-47	21	30	100
23	5687	1	5745	5620	1	5797	5336	1	4874	5761
22	3920	1	4056	3912	1	-4670	-3894	1	5108	5286
21	3392	1	3451	3485	1	-4140	-4103	1	4875	4856
20	3525	1	3566	3745	1	-4018	-4713	1	4891	4675
19	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	-517	476
17	1	1	1	1	1	1	1	-504	507	9
16	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1
8	280	278	274	269	261	250	236	219	196	146
7	279	276	272	266	259	248	235	223	201	166
6	277	275	271	265	257	247	236	225	208	191
5	275	272	268	262	255	246	237	228	223	228
4	273	271	267	261	254	246	238	233	234	247
3	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1

RELATIVE PERMEABILITY LOCATION = 1 PROBLEM LJ51

J	11	12	13	14	15	16	17	18	19	20
29	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1
25	100	137	247	943	-4008	-5259	-5659	-4946	-4946	5660
24	-137	104	423	5725	1252	-1685	-5774	1720	1720	-5774
23	1	124	81	1	56	56	1	52	52	1
22	1	88	96	1	55	55	1	52	52	1
21	1	88	85	1	56	56	1	54	54	1
20	1	101	100	1	75	75	1	74	74	1
19	1	1	1	1	1	1	1	1	1	1
18	1	143	66	1	86	83	1	89	89	1
17	-14	-31	27	516	177	149	520	220	220	520
16	60	-70	215	229	273	370	372	387	387	372
15	154	-227	209	244	272	281	295	301	301	295
14	224	-211	231	237	243	250	254	256	256	254
13	215	225	225	229	232	234	236	237	237	236
12	215	216	220	223	225	226	228	228	228	228
11	205	209	212	216	219	222	224	225	225	224
10	195	197	203	209	216	223	226	228	228	226
9	148	168	191	212	227	236	241	244	244	241
8	73	160	211	239	260	275	285	289	289	285
7	159	183	249	296	326	351	370	382	382	370
6	209	250	302	355	407	433	455	465	465	455
5	257	318	391	448	488	510	517	-517	-517	517
4	289	376	459	506	-517	-516	504	510	510	504
3	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1

RELATIVE PERMEABILITY   LOCATION = 1   PROBLEM LJ51

J	21	22	23	24	25	26	27	28	29	30
29	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1
25	5257	4014	945	247	137	100	62	35	27	34
24	1685	-1252	-5724	423	104	-137	100	-30	21	-47
23	56	57	1	81	124	1	5760	4875	1	5336
22	55	55	1	96	88	1	5283	5107	1	3894
21	56	56	1	85	88	1	4855	4873	1	4103
20	74	75	1	100	101	1	4672	4889	1	4713
19	1	1	1	1	1	1	1	1	1	1
18	83	85	1	66	143	1	476	-517	1	1
17	149	177	516	27	-31	-14	9	-507	504	1
16	370	273	229	215	-70	60	1	1	1	1
15	281	272	244	209	-227	155	1	1	1	1
14	250	243	237	231	-211	224	1	1	1	1
13	234	232	229	225	225	215	1	1	1	1
12	226	224	223	220	216	214	1	1	1	1
11	221	219	216	212	209	205	1	1	1	1
10	223	216	209	203	197	195	1	1	1	1
9	236	227	213	191	168	148	1	1	1	1
8	275	260	-239	211	160	73	146	196	219	236
7	351	326	296	249	183	160	167	201	223	236
6	433	407	355	302	250	209	191	208	225	236
5	510	488	448	391	318	257	228	223	228	237
4	-516	-517	506	459	376	290	247	234	234	239
3	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1

RELATIVE PERMEABILITY LOCATION = 1 PROBLEM LJ51

J	31	32	33	34	35	36
29	1	1	1	1	1	1
28	1	1	1	1	1	1
27	1	1	1	1	1	1
26	1	1	1	1	1	1
25	27	23	30	29	24	30
24	-29	-17	-39	-34	-18	-37
23	5797	1	5619	5745	1	5683
22	4669	1	-3912	-4056	1	3913
21	4139	1	-3487	-3452	1	3392
20	4018	1	3747	-3570	1	-3530
19	1	1	1	1	1	1
18	1	1	1	1	1	1
17	1	1	1	1	1	1
16	1	1	1	1	1	1
15	1	1	1	1	1	1
14	1	1	1	1	1	1
13	1	1	1	1	1	1
12	1	1	1	1	1	1
11	1	1	1	1	1	1
10	1	1	1	1	1	1
9	1	1	1	1	1	1
8	251	261	269	275	279	281
7	249	259	267	273	277	279
6	247	257	265	271	275	277
5	246	255	263	269	273	275
4	246	254	261	267	271	273
3	1	1	1	1	1	1
2	1	1	1	1	1	1
1	1	1	1	1	1	1

PRINT VECTOR POTENTIAL
$
VECTOR POTENTIALS IN WB/M   LOCATION = 1   PROBLEM LJ51

DIVIDE TABLE BY SCALE FACTOR
SCALE FACTOR = .176E 06

J	1	2	3	4	5	6	7	8	9	.10
29	919	916	905	886	860	827	788	741	689	68
28	929	925	914	896	870	836	796	749	696	68
27	986	983	971	952	924	889	845	794	736	67
26	1091	1089	1078	1056	1029	991	940	882	815	73
25	4697	4780	4774	4665	4715	4695	4552	4532	4492	4281
24	8008	8546	8543	7976	8480	8470	7848	8245	8224	7410
23	8610	8710	8709	8578	8648	8646	8409	8391	8387	7643
22	8858	8875	8875	8831	8819	8818	8659	8546	8542	7766
21	9045	9040	9040	9023	8993	8989	8870	8711	8687	7876
20	9249	9206	9205	9238	9173	9154	9123	8922	8786	8012
19	9253	9229	9226	9242	9199	9175	9130	8969	8807	8013
18	9297	9293	9292	9293	9280	9263	9229	9135	8971	8502
17	9353	9353	9356	9360	9363	9370	9387	9443	9581	9544
16	9409	9411	9417	9428	9443	9467	9506	9571	9645	9651
15	9462	9465	9475	9491	9515	9550	9599	9668	9731	9755
14	9509	9513	9525	9546	9576	9618	9673	9745	9809	9842
13	9549	9554	9568	9591	9626	9672	9731	9806	9872	9908
12	9580	9586	9601	9627	9663	9712	9774	9851	9919	9956
11	9602	9608	9624	9651	9689	9739	9803	9880	9948	9985
10	9613	9619	9636	9663	9702	9754	9818	9895	9962	9997
9	9614	9620	9637	9665	9704	9755	9819	9896	9962	9992
8	8422	8428	8442	8467	8501	8546	8600	8660	8709	8727
7	7229	7233	7246	7267	7296	7334	7379	7425	7461	7464
6	6034	6038	6049	6066	6090	6121	6156	6190	6215	6206
5	3072	3074	3079	3087	3098	3112	3126	3138	3142	3124
4	108	107	107	-105	103	101	97	93	88	82
3	98	98	97	96	94	91	88	83	78	73
2	93	93	92	91	89	86	82	78	73	68
1	92	92	91	90	88	85	81	77	72	67

VECTOR POTENTIALS IN WB/M   LOCATION = 1   PROBLEM LJ51

DIVIDE TABLE BY SCALE FACTOR
SCALE FACTOR = .176E 06

J	11	12	13	14	15	16	17	18	19	20
29	570	505	437	367	295	222	149	75	0	-73
28	575	509	440	369	296	223	149	75	0	-73
27	602	529	455	380	304	228	152	76	0	-75
26	648	561	477	393	312	233	155	77	0	-76
25	3924	3703	3484	3106	2577	2160	1575	555	1	-552
24	6906	6886	5687	4289	4264	2860	1446	1418	1	-1416
23	6935	6925	5585	4289	4267	2860	1447	1420	1	-1417
22	6983	6969	5644	4304	4277	2868	1453	1421	1	-1418
21	7058	7017	5677	4341	4284	2879	1472	1411	1	-1408
20	7212	7014	5739	4463	4222	2896	1568	1325	1	-1323
19	7238	7031	5739	4470	4226	2896	1569	1325	1	-1323
18	7461	7261	5982	4458	4329	2923	1502	1401	1	-1399
17	9376	7931	6492	5461	4294	3164	2144	1067	1	-1065
16	9611	8288	7105	5847	4652	3488	2316	1158	0	-1156
15	9750	8524	7260	6041	4821	3608	2404	1201	0	-1199
14	9846	8600	7367	6129	4898	3671	2445	1222	0	-1221
13	9916	8671	7425	6183	4943	3705	2469	1234	0	-1233
12	9964	8713	7464	6216	4970	3726	2483	1241	0	-1240
11	9992	8735	7482	6230	4981	3733	2486	1242	0	-1241
10	10000	8735	7472	6212	4959	3712	2470	1234	0	-1233
9	9981	8649	7361	6104	4866	3641	2423	1211	0	-1210
8	8647	8020	6956	5812	4651	3489	2326	1163	0	-1162
7	7356	6955	6230	5291	4271	3213	2144	1072	0	-1071
6	6099	5809	5293	4569	3717	2799	1864	929	0	-928
5	3066	2939	2706	2353	1917	1440	954	477	0	-476
4	74	66	57	47	38	29	19	9	0	-9
3	66	59	51	43	35	26	17	9	0	-8
2	62	55	48	41	33	25	16	8	0	-8
1	61	54	47	40	32	24	16	8	0	-8

VECTOR POTENTIALS IN WB/M   LOCATION = 1   PROBLEM LJ51

DIVIDE TABLE BY SCALE FACTOR
SCALE FACTOR = .176E 06

J	21	22	23	24	25	26	27	28	29	30
29	-147	-220	-293	-365	-435	-504	-569	-631	-688	-740
28	-148	-222	-295	-367	-438	-507	-574	-637	-695	-748
27	-150	-226	-302	-378	-454	-528	-600	-670	-735	-793
26	-153	-231	-310	-392	-475	-560	-646	-733	-813	-881
25	-1572	-2157	-2575	-3104	-3482	-3702	-3923	-4281	-4492	-4531
24	-1444	-2854	-4262	-4287	-5686	-6885	-6905	-7410	-8223	-8244
23	-1445	-2855	-4265	-4287	-5583	-6924	-6934	-7643	-8386	-8391
22	-1450	-2863	-4275	-4302	-5642	-6969	-6982	-7765	-8541	-8546
21	-1469	-2874	-4282	-4339	-5676	-7017	-7057	-7875	-8686	-8710
20	-1565	-2893	-4220	-4461	-5738	-7013	-7211	-8011	-8785	-8921
19	-1567	-2893	-4223	-4468	-5738	-7030	-7237	-8012	-8806	-8968
18	-1499	-2921	-4327	-4456	-5981	-7260	-7461	-8501	-8970	-9134
17	-2142	-3162	-4292	-5460	-6491	-7929	-9374	-9543	-9579	-9442
16	-2314	-3486	-4651	-5845	-7104	-8286	-9609	-9649	-9644	-9570
15	-2402	-3606	-4820	-6039	-7258	-8522	-9749	-9754	-9730	-9666
14	-2444	-3669	-4896	-6128	-7365	-8598	-9845	-9840	-9808	-9744
13	-2468	-3704	-4942	-6181	-7423	-8670	-9914	-9907	-9871	-9804
12	-2482	-3725	-4969	-6215	-7463	-8712	-9962	-9954	-9917	-9849
11	-2485	-3732	-4979	-6228	-7481	-8734	-9991	-9984	-9947	-9879
10	-2470	-3711	-4957	-6211	-7471	-8734	-9998	-9995	-9961	-9894
9	-2423	-3640	-4865	-6102	-7359	-8648	-9979	-9991	-9961	-9895
8	-2325	-3488	-4650	-5810	-6955	-8019	-8646	-8726	-8709	-8660
7	-2144	-3212	-4270	-5289	-6229	-6954	-7355	-7463	-7460	-7424
6	-1863	-2798	-3716	-4568	-5291	-5808	-6098	-6205	-6214	-6189
5	-954	-1440	-1916	-2352	-2705	-2939	-3065	-3123	-3141	-3138
4	-19	-28	-38	-47	-57	-66	-74	-81	-88	-93
3	-17	-26	-35	-43	-51	-59	-66	-72	-78	-83
2	-16	-25	-33	-40	-48	-55	-62	-68	-73	-78
1	-16	-24	-32	-40	-47	-54	-61	-67	-72	-77

VECTOR POTENTIALS IN WB/M LOCATION = 1 PROBLEM LJ51

DIVIDE TABLE BY SCALE FACTOR
SCALE FACTOR = .176E 06

J	31	32	33	34	35	36
29	-787	-826	-860	-885	-904	-915
28	-795	-835	-869	-895	-914	-925
27	-844	-888	-923	-951	-970	-982
26	-939	-990	-1028	-1055	-1077	-1089
25	-4552	-4696	-4716	-4665	-4774	-4779
24	-7847	-8468	-8479	-7976	-8542	-8545
23	-8408	-8645	-8647	-8577	-8708	-8709
22	-8659	-8817	-8818	-8830	-8874	-8874
21	-8869	-8988	-8992	-9022	-9039	-9039
20	-9122	-9153	-9172	-9237	-9204	-9205
19	-9129	-9174	-9198	-9241	-9226	-9228
18	-9228	-9263	-9279	-9292	-9291	-9292
17	-9386	-9369	-9362	-9359	-9355	-9352
16	-9505	-9466	-9442	-9427	-9416	-9410
15	-9598	-9549	-9514	-9490	-9474	-9465
14	-9672	-9617	-9575	-9545	-9525	-9513
13	-9730	-9671	-9625	-9591	-9567	-9553
12	-9773	-9711	-9662	-9626	-9600	-9585
11	-9802	-9738	-9688	-9650	-9623	-9607
10	-9816	-9753	-9701	-9663	-9635	-9619
9	-9818	-9754	-9703	-9664	-9636	-9620
8	-8599	-8545	-8500	-8466	-8442	-8427
7	-7378	-7333	-7296	-7266	-7246	-7233
6	-6155	-6120	-6090	-6065	-6048	-6038
5	-3126	-3111	-3098	-3087	-3079	-3074
4	-97	-101	-103	-105	-106	-107
3	-87	-91	-94	-96	-97	-98
2	-82	-86	-89	-91	-92	-93
1	-81	-85	-87	-90	-91	-92

FLUX

Program FLUX and associated subroutines provide the graphical output for this analysis. The graphics terminal has a hard-copy unit for making a permanent record of the CRT display.

The first picture (Figure 1) provides a record of the alternator configuration under consideration in problem LJ51. Dashed lines represent internal boundaries which clearly outline iron-air interfaces for rotor and stator. The upper and lower dashed lines are iron-air interfaces for airspace used to reduce the flux through these regions to zero. Stator and damper slots are shown although current values are not considered for either during this analysis.

In response to input of parameter 1 on the control teletypewriter, the magnetic field is drawn over the machine outline (Figure 2). This plot is equal values of magnetic induction, B. Series of closed curves are drawn which are symmetrical around the pole centerline. In several cases, the curves close on themselves across the vertical boundaries of the configuration. In those instances where curves appear to fail to close, this problem is really no indication that the solution algorithm has failed but that the program for drawing the display has failed at that point.

In response to input of parameter 2 on the control teletypewriter, the magnetic vector potential is drawn over the machine outline (Figure 3). The equipotential lines form closed curves which display a symmetrical relation around the pole centerline. These curves represent flux lines, and the flux lines at opposite vertical boundaries are in opposite direction just as the sign reversal in magnitudes of magnetic vector potential maps printed by the previous program.

A modification was made in this program to print curves of small interval near the maximum and minimum values of the magnetic vector potential. This modification tends to isolate the kernels which occur in the field coil winding on the rotor. The record also shows paths of leakage flux which occur in air between field poles. Note the flux lines at the iron-air interface are perpendicular as desired (Figures 4 and 5).

The number of lines to be plotted may be specified. The more lines requested, the smaller the interval between equipotential lines. The number of lines drawn is specified and should not be interpreted as degree of magnetic saturation.

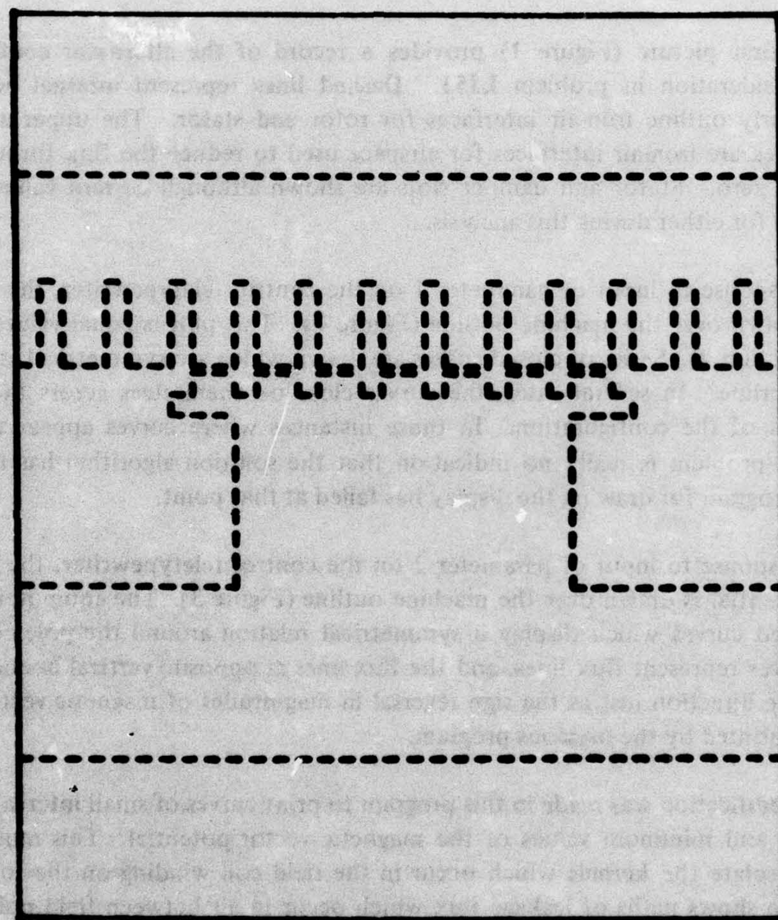

Figure 1. LJ51 Machine Grid (10 Feb 76).

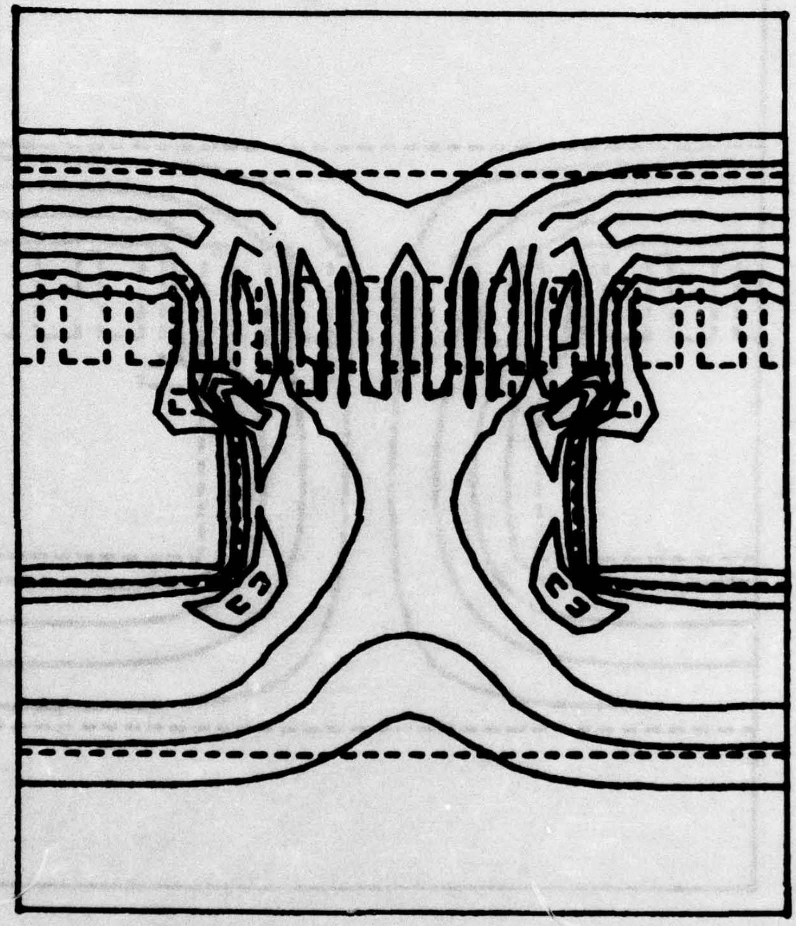

Figure 2. LJ51 Magnetic Field (11 Feb 76): PRINB MOD; PLOTB MOD; FLUX MOD.

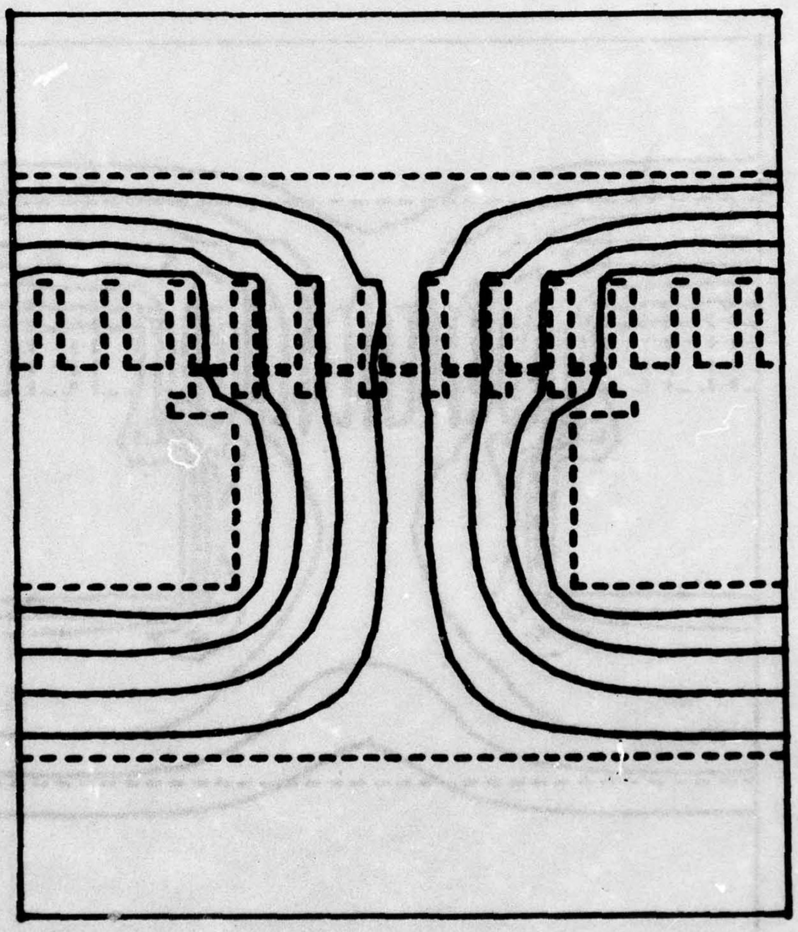

Figure 3. LJ51 Vector Potential (11 Feb 76):
PRINB MOD; PLOTB MOD; FLUX MOD; 10 LINES.

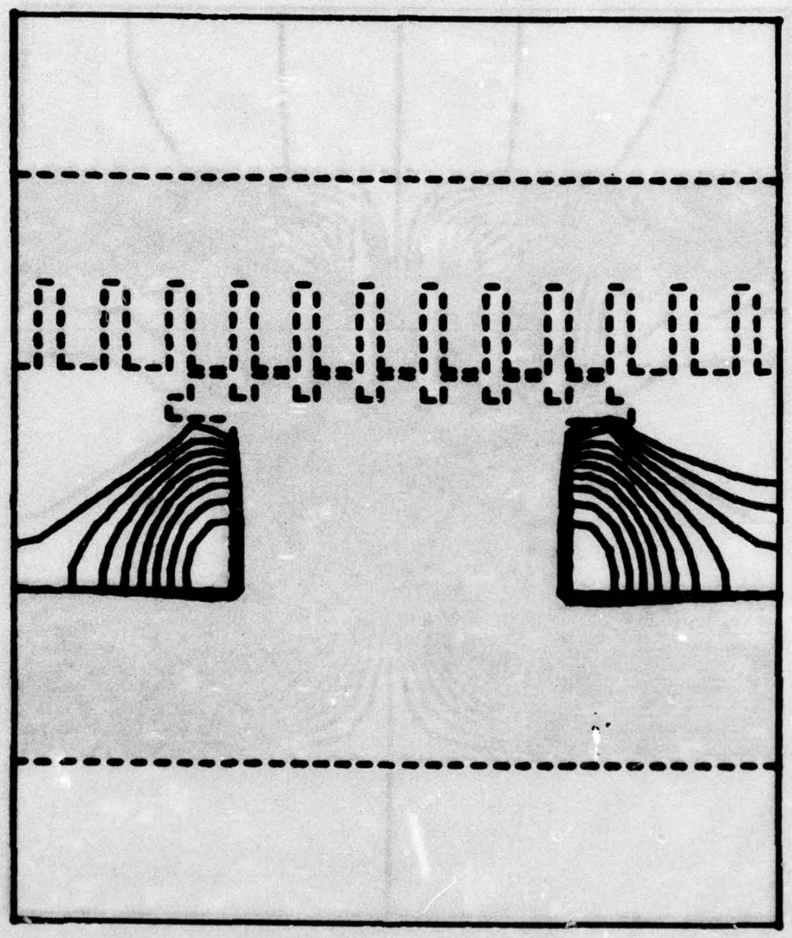

Figure 4. Modification in the program. (Note the flux lines at iron-air interface are perpendicular as desired.)

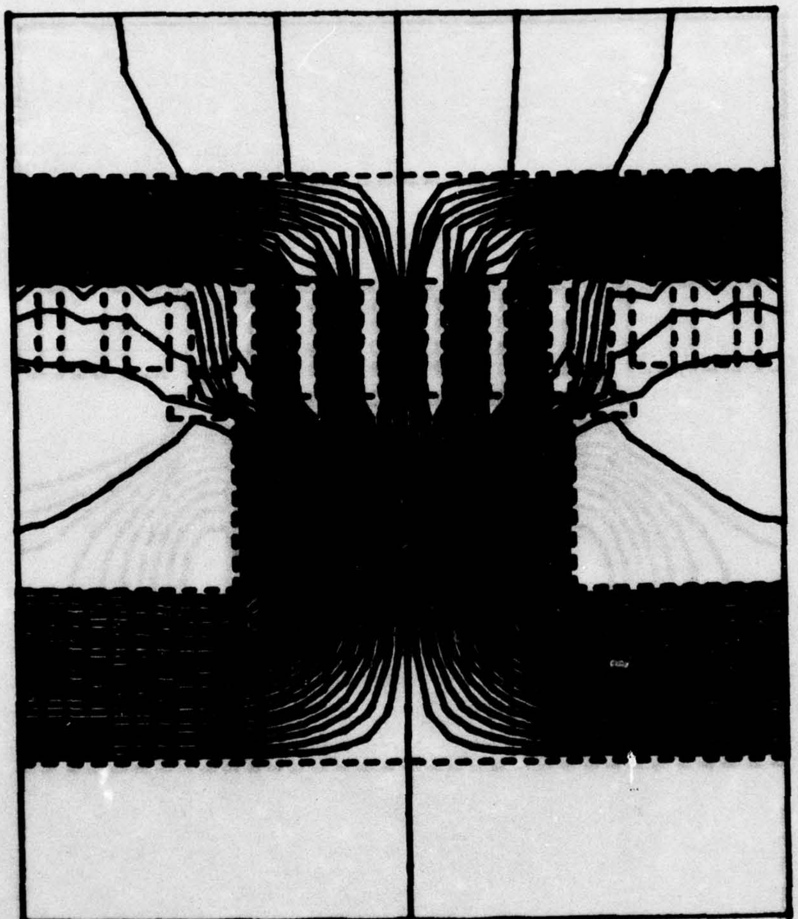

Figure 5. Modification in the program.

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